Vol. XI, Part V October, 1941

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority

of

The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 23*s*. 6*d*.

Price per part
Rs. 3 or 5s.

Published by the Manager of Publications, Delhi
Printed by the Manager, Government of India Press, New Delhi
1941

ICAR. 5. XI.5
750

The Editorial Committee, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Imperial Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

Instructions to Authors

Articles intended for The Indian Journal of Agricultural Science should be accompanied by short popular abstracts of about 300 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state ' Original not seen '.

Sources of information should be specifically acknowledged.

As the *format* of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{8}$ in. $\times$ $9\frac{5}{8}$ in. cut), no text-figure, when printed, should exceed $4\frac{1}{2} \times 5$ inches. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in. $\times$ 8 in. exclusive of that for letterpress printing.

Copies of detailed instructions can be had from the Secretary, Imperial Council of Agricultural Research, New Delhi.

CONTENTS

VOL. XI, PART V

(October 1941)

The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal.

		PAGE
Original articles—		
THE GENUS *FUSARIUM*, VI. A RECENT ATTEMPT AT MASS REVISION	*G. Watts Padwick* . .	663
STUDIES IN INDIAN CEREAL SMUTS, II. VARIETAL RESISTANCE OF INDIAN AND OTHER WHEATS TO LOOSE SMUT (WITH PLATE XXXVI AND ONE TEXT-FIGURE)	*B. B. Mundkur and B. P. Pal*	675
STUDIES IN INDIAN CEREAL SMUTS, III. VARIETAL RESISTANCE OF INDIAN AND OTHER WHEATS TO FLAG SMUT	*B. P. Pal and B. B. Mundkur*	687
STUDIES IN INDIAN CEREAL SMUTS, IV. VARIETAL RESISTANCE OF INDIAN AND OTHER OATS TO SMUTS	*R. D. Bose and B. B. Mundkur*	695
VARIATION IN THE MEASURABLE CHARACTERS OF COTTON FIBRES, II. VARIATION AMONG SEEDS WITHIN A LOCK (WITH PLATE XXXVII AND TWO TEXT-FIGURES)	*R. L. N. Iyengar* . .	703
STUDIES ON PROPAGATION OF THE MANGO, *MANGIFERA INDICA* L. (WITH PLATES XXXVIII AND XXXIX)	*K. C. Naik* . . .	736
THE COLD STORAGE OF PEARS (BARTLETT) IN THE PUNJAB (WITH PLATE XL AND ONE TEXT-FIGURE)	*Lal Singh and Abdul Hamid*	769
CITRUS MANURING, I. FERTILIZER EXPERIMENT WITH SWEET ORANGE (MALTA) GROWING ON ROUGH LEMON (WITH ONE TEXT-FIGURE)	*Lal Singh, Bal Singh and A. A. Khan*	778
A KEY FOR THE IDENTIFICATION OF LARVAE OF THE KNOWN LEPIDOPTEROUS BORERS OF SUGARCANE IN INDIA BASED ON MORPHOLOGICAL CHARACTERS (WITH PLATES XLI—XLV)	*P. V. Isaac and K. V. Rao*	795
A KEY FOR THE IDENTIFICATION OF PUPAE OF THE KNOWN LEPIDOPTEROUS BORERS OF SUGARCANE IN INDIA BASED ON MORPHOLOGICAL CHARACTERS (WITH PLATES XLVI—L)	*P. V. Isaac and T. V. Venkatraman*	807

PAGE

SCALE INSECTS OF THE PUNJAB AND NORTH-WEST FRONTIER PROVINCE USUALLY MISTAKEN FOR SAN JOSÉ SCALE WITH DESCRIPTION OF TWO NEW SPECIES (WITH PLATES LI—LIII) — *Khan A. Rahman and Atiqur Rahman* . . . 816

Abstract 831

Reviews—

HANDBOOK OF ECONOMIC ENTOMOLOGY FOR SOUTH INDIA . . . 832

THE GRASSLANDS OF THE ARGENTINE AND PATAGONIA . . . 832

Plant Quarantine Notifications 834

ORIGINAL ARTICLES

THE GENUS *FUSARIUM*

VI. A RECENT ATTEMPT AT MASS REVISION

BY

G. WATTS PADWICK

Imperial Mycologist, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 22 February 1941)

RECENTLY there appeared a brief paper by Snyder and Hansen [1940] which is certain to attract a great deal of attention by plant pathologists and mycologists interested in the important genus, *Fusarium*, the world over. In it they formally convert all the species, varieties or physiologic forms of *Fusarium* in the section Elegans, totalling 41 in number, into one single species, *Fusarium oxysporium* Schlecht., the description of which they emend to agree with that of the section Elegans given by Wollenweber [1913]. The species they regard as being divided into physiologic forms differing merely in pathogenicity and capable of identification by virtue of the diseases they cause. It is claimed that an analysis of a large number of single-spore isolates has shown the capacity of Elegans *Fusaria* to produce both sporodochial and non-sporodochial types of variants and relatively large or small macroconidia in the progeny from a single conidium. This, they say, at once makes untenable the present basis for division of the section into the three sub-sections and by the same token invalidates the species in them. The species *F. oxysporum* (in the emended sense) can, they add, be determined readily on morphological criteria, and the biologic forms by pathogenicity tests. The system is said to be readily usable and to give the plant pathologist a clearer concept of the nature of the fungi with which he is dealing. It is claimed that the taxonomic system proposed merely modified Wollenweber's system, into the main framework of which (i.e. Wollenweber's grouping in sections) it fits well.

Such mass revision is unusual in any group of plants, and on this account, coupled with the tremendous economic importance of this group of fungi which cause the majority of wilt diseases of economic crops, taxonomists and pathologists alike will naturally wish to investigate the validity of the changes. There is no doubt that if found valid and acceptable the proposals will be adopted with enthusiasm, for it will then unquestionably bring to an end all the confusion that has existed hitherto in the taxonomy of the group. The problem can be best tackled by first studying the way in which the section Elegans and its related sections, Liseola and Lateritium, were erected and revised, and the present conception concerning them.

Origin of the sections of *Fusarium* and their present status

Wollenweber [1913] started dividing the genus *Fusarium* into sections 'in order to unite species having related characters, the most important of which is a uniform shape of conidia'. He erected the sections Martiella, Elegans, Discolor, Gibbosum, Roseum and Ventricosum. His description of the section Elegans is as follows :—

'All species have scattered, ellipsoidal, unicellular conidia, averaging $5\text{-}12 \times 2\text{-}3{\cdot}5\mu$ in size. Many species have also sporodochia with a sclerotial base and pionnotes. The sickle-shaped conidia have the form of the Elegans type (Figs. E, F, S), mostly 3-septate, but also 4 and 5-septate. The average size differs according to the species, the majority having 3-septate conidia, $25\text{-}40 \times 3\text{-}4{\cdot}5\mu$, while the 4-septate are somewhat larger, and the 5-septate average $40\text{-}50 \times 3\text{-}4{\cdot}5\mu$. Conidia in masses, mostly salmon-coloured, but in some species brownish-white, in others brilliant orange. Conidiophores verticillately branched in sporodochia (Fig. V). Chlamydospores ellipsoidal, terminal and intercalated (Fig. T, V), the unicellular ones being $5\text{-}10\mu$, the 1-septate ones up to 12μ. Ascerigous state unknown.

Species in the section are : *Fusarium oxysporum* (Schlecht.), *F. tracheiphilum* Smith, *F. vasinfectum* (Atk.), *F. lycopersici* Sacc., *F. niveum* Smith, *F. redolens* n. sp., *F. orthoceras* App. and Wr., *F. conglutinans* n. sp., notes on which follow'.

Wollenweber regarded the presence of a wine-red colour on rice as a striking character of typical species of the section Elegans, though he mentioned it only incidentally, and not in the description of the section, and the new species *F. conglutinans* was distinguished from other members by lack of this colour.

Wollenweber illustrated the difficulty of basing taxonomic decisions merely on studies of exsiccatae, when we have no criterion of the degree of maturity of the organs investigated. Maire separated species of *Hypomyces* with obtuse ascospores from Plowright's *Hypomyces* and established the new genus *Nectriopsis*, the ascospores of which have an apiculate end. This was due merely to the fact that Maire was studying, in some cases, immature ascospores.

Wollenweber [1917] divided the section Elegans into three sub-sections, but did not describe them. They contained the following species :—

Sub-section Orthocera

F. citrinum Wr.
F. orthoceras App. et Wr.
F. orthoceras App. et Wr. var. *albidoviolaceum* (Dasz.) Wr.
F. orthoceras App. et Wr. var. *longuis* (Sherb.) Wr.
F. asclerotium (Sherb.) Wr.
F. angustum Sherb.

Sub-section Constrictum

F. moniliforme Sheld.
F. bulbigenum Cke. et Mass.
F. batatatis Wr.

Sub-section Oxysporum (cyanostroma)

F. tracheiphilum (E. F. Smith) Wr.
F. vasinfectum Atk.
F. vasinfectum Atk. var. *inodoratum* Wr.

F. oxysporum Schlecht
F. oxysporum Schlecht emend. Wr.
F. hyperoxysporum Wr.
F. sclerotioides Sherb.
F. aurantiacum (Lk.) Sacc.
F. niveum E. F. Smith.

SUB-SECTION OXYSPORUM (PALLENS)

F. blasticola Rostrup
F. euoxysporum Wr.
F. zonatum (Sherb.) Wr.
F. lycopersici (Sacc.) Wr.
F. redolens Wr.

Thus the section Elegans (with its three sub-sections and two 'series') which originally contained eight species, was expanded to include 23 species and varieties. These have since undergone much change in position [Wollenweber and Reinking, 1935]. The species *F. moniliforme* Sheld. is now recognized as the type species of the important section Liseola. Four members of the sub-section Oxysporum have been transferred to Constrictum.

At the same time Wollenweber [1917] erected the section Lateritium, giving a Latin description, which may be translated as follows :—

'Mycelium white, rose, yellow, but never carmine, aerial to immersed, intercallary chlamydospores often, but terminal ones always, deficient : sclerotia nodular, rough, often of a dark blue colour, erumpent from a spreading stroma. Conidia brick-coloured, of the same form as species of the section Elegans, in tubercular sporodochia, in pionnotes or scattered in the aerial mycelium. Many species are now recognized as the conidial stages of *Gibberellae*'.

Fusarium uncinatum Wr. from *Cajanus indicus* (=*C. cajan*), Pusa India, was described, and it was mentioned that chlamydospores are absent. The following species were included in the section Lateritium :—

F. larvarum Fuck.
F. uncinatum Wr. (=*F. udum* Butl. [Padwick, 1940,2])
F. salicis Fuck.
F. salicis Fuck. var. *pallens* Wr.
F. lateritium Nees.
F. pyrochroum (Desm.) Sacc.
F. urticearum (Cda.) Sacc.
F. fructigenum Fries.
F. fructigenum Fr. var. *majus* Wr.
F. sarcochroum (Desm.) Sacc.
F. robiniae Pass.

Thus, the section was made to comprise 11 species and varieties (with imperfect stages of certain species of *Gibberella*), of which only two still stand as good species of this section, four having come to be regarded as synonymous with *F. lateritium* Nees, three as varieties of that species, and one (*F. robiniae* Pass.) having been found synonymous with *F. sarcochroum*. *Fusarium larvarum* Fuck. has since been transferred to the section Arachnites, although that section was already existing at the time.

In the following year Wollenweber [1918] gave a Latin description of the section Elegans, with reference to his original description published in 1913, together with very brief Latin descriptions of the sub-sections Orthocera and Oxysporum, which may be translated as follows :—

'Microconidia mostly simple, $5\text{-}12 \times 2\text{-}3.5\mu$: macroconidia free, in tubercularia-like sporodochia or running together in pionnotes, straight in some species, more or less falcate in others, more curved at the apices than at the middle, pointed to constricted on both sides, more or less pedicellate at the base. Azure blue sclerotia formed in many species. This section, which otherwise strongly resembles Lateritium, differs in its abundant production of microconidia and terminal chlamydospores.

α. Sub-section Orthocera Wr.

Sporodochia imperfect and frequently quite lacking, microconidia typically present. Length of the conidia nine to twelve times their width.

Examples : *F. orthoceras* App. et Wr., *F. citrinum* Wr.

β Sub-section Oxysporum Wr.

Sporodochia typically present. Stroma more or less erumpent and warty, sclerotial. Length of the conidia eight to ten times their width.

A series Cyanostroma

Stroma more or less erumpent and tinted azure blue

Examples : *F. tracheiphilum* (Erw. Sm.) Wr., *F. vasinfectum* Atk., *F. oxysporum* Schlecht., *F. sclerotioides* Sherb., *F. aurantiacum* (Lk.) Sacc.

A series Pallens.

Stroma pale and gelatinous, rarely erumpent ; sporodochia readily coalescing.

Examples : *F. euoxysporum* Wr., *F. zonatum* (Sherb.) Wr., *F. redolens* Wr.'

Wollenweber, Sherbakoff, Reinking, Johann and Bailey [1925] recorded the results of carefully considered investigations on the genus *Fusarium*. They recognized the existence of 'borderline strains' between sections. They pointed out that the production of the 'norm'—that is, generally speaking, macroconidia—is necessary for proper identification, but that microconidia may have definite characters which aid in the determination of the section and in exceptional cases may even lead to the identification of the species. They point out that colours of the conidia and colour of the aerial mycelium and stroma are further reliable characters for taxonomy, e.g. rose to wine-red or lilac is typical of many species of section Elegans, carmine red of Discolor, Roseum and Sporotrichiella, and citric or sulphuric yellow of the sub-section Neesiola. It is of especial interest to us that chlamydospores, by their presence or absence, indicate the border of certain groups with similar macroconidia, notably Elegans and Lateritium, while sclerotia may be characteristic for groups, such as Lateritium.

Wollenweber, Sherbakoff, Reinking, Johann and Bailey described the new section Liseola, which (translated) is as follows :—

'Section Liseola (Syn. Constrictum Wr. pro parte subs. Elegantis ; Moniliforme Sherb.) microconidia more or less methodically arranged in chains, fusoid to ovoid, macronidia of the form and colour of Lateritium, free or in sporodochia or pionnotes : chlamydospores absent : stroma violet. Conidial states of *Gibberella* of the section Lisea (Sacc.)'.

From the key to sections given by these authors we also get a much clearer conception of the section Elegans than was given by Wollenweber in 1913. Thus, we learn that the microconidia are not in chains (one reason why the Liseola *Fusaria* were separated from this section) ; that the conidial walls are thin, and that the conidial masses are brownish to salmon on a vinaceous to lilac, but never green, stroma, all important characters

distinguishing Elegans from Martiella. We also learn that conidia of Elegans, Liseola and Lateritium are practically indistinguishable in their form, thinness of walls, and colour, and that the only important differences are in microconidia and chlamydospores. Lateritium has no typical microconidia, Liseola has them arranged in chains, Elegans has them singly or in false heads ; Liseola and Lateritium have no chlamydospores. Elegans has them both terminal and intercallary.

At about this time Wollenweber and Reinking [1925] indicated the changes in value which had come to be accepted for various characters. They pointed out that the general type of macroconidia, at one time regarded as the most important character in the taxonomy of *Fusaria*, has proved to be of more value when considered in conjunction with other characters, for example the presence of microconidia, chlamydospores, sporodochia and pionnotes. They point out how closely allied are the sections Liseola, Lateritium and Elegans.

The most elaborate description of the various sections of *Fusarium* appears in Wollenweber and Reinking's [1935] book '*Die Fusarien*'. The description of the section Elegans, though more complete than previously given in the articles mentioned above, is altered in only one important aspect ; it is mentioned that whereas in some species the macroconidia are long, spindle-needle-shaped, tapering at both ends or slightly constricted, in other cases they are more compact, spindle-sickle-shaped with constricted, and frequently somewhat hooked, apices. These hooked spores are also common in Lateritium, as now mentioned in the description of this section. The terminal chlamydospores are again described as absent in Lateritium, the intercallary ones in the conidia and mycelium as more or less copious. If we see the descriptions of the species, however, we find that in many cases the chlamydospores are entirely lacking, as stated in the key given by Wollenweber *et al.* [1925]. In a later publication, Wollenweber himself [1938] says that chalmydospores do occur terminally on occasions in the fungus *Fusarium lateritium* Nees var. *uncinatum* Wr. From Wollenweber and Reinking's work we furthermore learn that the varieties *minus* and *uncinatum* both produce copious microconidia in the aerial mycelium. Thus, the two sections, Elegans and Lateritrium, remain similar in spore form ; the only difference lies in their less frequent production of terminal chlamydospores and of typical microconidia, or rather in the restriction of these to one or two varieties, and in the lack of wine-red colour in the section Lateritium.

The conception of the group Liseola has undergone considerable alteration. Only half of its members have typical chains of microconidia. As in the case of Lateritium and Elegans, some members have distinctly hooked macroconidia (*F. moniliforme* Sheld. var. *anthophilum* (A. Br.) Wr. and *F. lactis* Pir. *et* Rib.) All the species lack chlamydospores, but so, for that matter, do *F. stilboides* Wr. and *F. sarcochroum* (Desm.) Sacc. of Lateritium.

Where now is the dividing line between the three sections, Elegans, Lateritium and Liseola ?

Overlapping of groups

It has been clearly shown that since the sections Elegans, Lateritium, and Liseola were erected, the conception of these three groups has so altered

that they are no longer entirely distinct. This does not mean that the descriptions of all these groups of plants are identical, or that all three define exactly the same group of plants. It does mean that they overlap one another to a very marked degree. Since a group of plants is composed of individuals, it means that although there are certain plants which could find a place in only one of the groups, there are others which could conceivably be placed in either of two groups, or even in all three groups.

One of the most difficult fungi to place in its correct group is *Fusarium udum* Butl., the cause of wilt of pigeon-pea and sunn-hemp. Butler [1910] described this fungus in 1910. Later on he [Butler, 1926] regarded it as a synonym of *F. vasinfectum* Atk. Wollenweber [1938] placed it in the section Elegans. I have shown [Padwick, 1940,2], however, that it is the same as *F. lateritium* Nees var. *uncinatum* Wollenweber and that the latter fungus is synonymous with *F. udum*. As to the section to which it belongs, however, I make no pretence at being able to say. *F. lateritium* Nees is the typical species of the section Lateritium and one would presume that a variety of the same species must belong to the same section. When chlamydospores are formed, however, they are frequently terminal not only in isolates obtained by the author from several places in India, but also in Wollenweber's own culture obtained from Baarn. Judged by this criterion, it could not belong to section Lateritium, but must be placed in Elegans. At the same time, there are otherwise identical cultures which so far have not been induced to form typical chlamydospores, and it would seem that these cultures might just as well be placed in section Liseola as section Lateritium, though not in section Elegans. Thus, there are a number of cultures all able to cause piegon-pea wilt, falling into at least two, and perhaps three, sections. I have revived the species *F. udum* Butl., and have concluded that all the isolates causing pigeon-pea wilt and sunn-hemp wilt are one species. Otherwise, we must have almost as many species as isolates—an impossible situation. In fact, this and no other is exactly the conclusion which Snyder and Hansen would have had to reach, had they studied many isolates causing pigeon-pea wilt, and which they did reach by inference having studied only closely related fungi.* But if complete mergence of forms means synonymy, all members of sections Elegans, Lateritium, and perhaps Liseola must be merged into one species. The history of the sections outlined above and their true descriptions, that is to say, their emended descriptions, prove it; *Fusarium udum* Butl. illustrates it. Both Liseola and Lateritium contain forms which are merely imperfect stages of Ascomycetes, species of *Gibberella*. Thus all the members with which we are dealing become synonyms of some *Giberella*.

I have one culture (referred to as 'F 169' by Pawick [1940,2] which causes wilt of sunn-hemp and which is difficult to place in its section, because although belonging to Elegans in other respects it is closer to Martiella in spore shape. Martiella *Fusaria* have Hypomyces for their perithecial form.

There appear to be two flaws in this argument. The first lies in the assumption made by Snyder and Hansen that we can say Wollenweber and his associates are all wrong in their grouping of isolates into species and yet

* Snyder, from whom an enquiry was made, stated that he had no culture of *F. udum*.

right in their grouping of species into sections. The second lies in the tendency to lose objectivity by concentrating on the potentialities of the species in test-tubes rather than its objective existence in nature.

In the genus *Fusarium* we have a jumble of ill-defined cultures, falling roughly into groups, some dintinctly recognizable as belonging to certain groups, others borderline cases. A number of workers, notably Professor W. Brown and his associates at the Imperial College, and now again Snyder and Hansen, have demonstrated the high degree of variability of 'species'. Take any representative of a so-called species, and you can show how atypical descendants resemble adjacent species. Arbitrary lines of demarcation have been selected to divide species from species and section from section. Borderline members of one species resemble borderline members of another; borderline members of one section are not clearly distinct from members on the outside rim of another; and so on all the way up the line. Who can say where *Cephalosporium* ends and *Fusarium* begins? Subramaniam and Chona [1938] have shown how difficult it is to distinguish a boderline *Cephalosporium* from a borderline *Fusarium* of the section Liseola. But we rightly retain *Cephalosporium* as a perfectly good genus.

Fusarium has been shown to be highly variable. To get always an exact determination is at present beyond the ability of mycologists. Many of the cultures which were worked with by Wollenweber were secured from the Centraalbureau voor Schimmelcultures and have been studied by the author in India, and they still retain after several years—after many generations—the characters they were said to possess. The author [Padwick, 1940, I] proposed the conversion of *F. conglutinans* Wr. into a synonym of *F. orthoceras* App. et Wr. but would go no further. Though there may be, and probably are, all the way through the genus and even into related genera, closely linking forms, and though one such form may give rise to descendants difficult to distinguish from a closely related form, there is no evidence so far that any particular form can give rise readily or at all to a more widely separated form. One would like to see evidence, for instance that the culture of *Fusarium bostrycoides* Wr. et Rkg. from Baarn can ever give anything even remotely resembling *Fusarium udum* in the so-called variable characters, colour and spore form.

By converting all the members of the section Elegans into one species, *F. oxysporum*, Snyder and Hansen have undoubtedly simplified enormously the ritual of giving a name to a large number of isolates. They have greatly reduced the possibility of making errors by the simple procedure of being vague. To infer, however, that borderline members of the section can be readily distinguished from borderline members of the sections Lateritium and Liseola, is contrary to the facts. The borders are as indistinct as ever To be consistent, they should have transferred them all to a *Gibberella*. Above all, to emend the description of *F. oxysporum* to that of section Elegans given by Wollenweber [1913] is to ignore all the contributions to our knowledge that have been made since that date. In addition, there is an assumption, implied at least, that pathogenicity is readily determined and constant. As a matter of fact, it is a slow method of identification, and requires exact definitions of environmental conditions and purity of the host rarely attainable

even in modern laboratories; as to the constancy of pathogenicity, there is a good deal of evidence to suggest that it is not all we would like it to be. Even as to distinctive specificity there are now grave doubts, for Hansford [1940] claims to have isolated from cotton Elegans ***Fusaria*** with a wide host range. One wonders by what subtle distinction of form or habit Snyder and Hansen, despite their strongly expressed opinions, believe that *F. oxysporum* f. *pisi* should be split up into two 'races', numbers 1 and 2, both causing wilt of *Pisum sativum*. Is it to be the start of a new series of sub-divisions based on undefined pathogenic symptoms, or is it merely a sign of lack of complete faith in their own protestations?

The pity of it all lies in the haste with which Snyder and Hansen have come out with a formal declaration of new names and synonymy. Thanks to the spade-work of Hansen and Smith [1932, 1938], we are probably nearer the correct basis for classification of these forms than ever before. Great possibilities now emerge. We require the stable elements of dual phenomenon, the homotypes, and we want them carefully and thoroughly described to the best of our ability. We want these descriptions based on pathogenicity and geographical distribution, which means that workers all over the world must collect, purify, and describe, and then emend descriptions on the basis of what they have seen, linking their descriptions up, if that is possible, with those of earlier workers, though most of the specimens on which the early descriptions were based are now mouldering piles of dust. These will give us focal points, objective groups upon which we can build our species and base our new deal in taxonomy. We are not ready for that yet, and in any case there is no hurry. When we have got our focal point species adequately described in the new way, with all our modern knowledge of variation, and our modern instruments of statistical measurement, of recording colours, of drawing and photography, we can change names with impunity. Until then, let caution be our watchword. When we eventually make the changes, let us make them with our eyes open and with due consideration of the history of cases and the objectivity of species.

Concept of a focal point species

Thom [1940], who has spent many years working with Penicillia and Aspergillae, has concluded that they become inextricably involved when large numbers of variants are compared, some of them passing into the Gymnoascus type of fruiting so completely as to make the differentiation of families a quite arbitrary arrangement. Indeed, the classification of groups higher than the species is much more an arbitrary and indecisive matter than that of species, because, while we can with our own eyes see the species as a group capable of perpetuating itself independently of related groups, with an objective existence in geographical position and with clear ecological relationship, available for recording of measurement by all methods of scientific approach, the higher ranks, the families and orders, are something upon which we can only hypothesize as having a phylogenetic relationship susceptible, at least in fungi where palaeontology gives us little guidance, of only rough and ready evolutionary interpretations. With what satisfaction, for instance, can any of us pretend to place the genera *Hypodermella* and *Schizothyrium* in their 'correct' families from an evolutionary point of view? For what

reason, other than one of convenience in identification by virtue of method of opening of the hypothecium, do we place the Tryblidiaceae amongst the Phacidiales instead of the Pezizales, to which they would seem to belong equally well ? Between the species of fungi, with their objective existence as concrete living ecological and geographical groups, and the classes, with their distinctive types of sexuality, lie ranks which in some groups are clear cut enough to command common agreement and in other cases are vague, indistinctive and unconvincing.

The work of Hansen and Smith has shown that there exists, in the 'dual phenomenon', something akin to a form of sexuality in many fungi. Akin to it, but yet not sexuality ; akin to chimaera formation, yet not that either. Though probably caryogamy does not take place in the cells resulting from hyphal fusions the effect is similar, namely the production of a number of phenotypes intermediate between the parental homotypes. As far as the taxonomic aspect goes, these intermediate forms are of much the same significance as impure segregating lines in sexually reproducing plants. The tendency to form hyphal fasions and resultant intermediate forms in these 'imperfect' fungi, and the influence of such inevitable intermediate forms on our taxonomic ideas, may receive similar consideration to borderline cases in sexually reproducing kinds of plants. Two quotations from Julian Huxley's introductory chapter to *The New Systematics* [1940] gives us some guidance here. The first of these deals with borderline cases :—

'Other border-line cases exist where a chain of forms, each at least sub-specifically nameable, but all connected by intergrading zones of interbreeding, is continued so far that its extremes would immediately be styled distinct species if the intermediates did not exist, and would doubtless behave as such if tested genetically. Carabid beetles provide an excellent example of this. Sometimes nature has actually performed the crucial experiment and range extensions have brought the end forms together in nature, when they do behave as good species in refusing to cross'.

The second deals with hybridization as a single factor criterion :—

'As Turrill [1938] has emphasized, the fact that groups may or might show fertile intercrossing when artificially or in other ways secondarily brought together does not disprove their right to be styled species. It is the actual facts of nature, not its every potentiality, with which the systematist has to deal. The fact of their separate existence *qua* self-perpetuating interbreeding groups, together with either a reduction or absence of fertility in inter-crossing, or a certain empirically evaluated degree of morphological or physiological characters, should be taken as the basis of decision.'

In our test-tube work with *Fusaria* we are dealing with the 'every potentiality' of the organisms, or rather, with every potentiality other than the 'actual facts of nature'. We must get down to studying these actual facts by collecting and describing from actual field material, looking for ecological and even geographical species, before we can safely erect a new taxonomy. This is the essence of the recent Presidential Address of Mason [1940] to the British Mycological Society, and it is inescapable.

Nomenclatural changes

On the basis of the reasoning outlined above, the following nomenclatural changes which have been recognized in the papers so far contributed to this series [Padwick, 1940 ; 1,2] are formally set forth with Latin diagnoses where required. It may be noted that it is not proposed to call the *Fusarium* causing

wilt of pigeon-pea (*Cajanus cajan*) *F. udum* var. *Cajani* as originally suggested since the original description of *F. udum* included mention of its pathogenicity.

The author is grateful to Dr B.B. Mundkur for suggestions regarding nomenclature and to Dr N. L. Bor of the Forest Research Institute for providing the Latin diagnoses.

Fusarium orthoceras App. et Wr. var. *conglutinans* (Wr.) Padwick, *Indian J. agric. Sci.* **10**, 282 : 1940

Syn. *F. conglutinans* Wr., *Phytopathology* 3, 30 ; 1913 ; *Ber. Deutsch. bot. Ges.* **31**, 31 : 1913

F. oxysporum Schl. f. *conglutinans* (Wr.) Snyder et Hansen, *Amer. J. Bot.* **27**, 66 : 1940

Morphologice a typo speciei haud distinguendum. Habitat in *Brassica oleacea* Linn. et speciebus cognatis, vitium vasculare in America boreali (U.S.A.) efficiens

Fusarium orthoceras App. *et* Wr. var. *Betae* (Stewart) Padwick, *Indian J. agric. Sci.* **10,** 282 : 1940

Syn. *F. conglutinans* Wr. var. *Betae* Stewart, *Phytopathology* **21**, 67 : 1931

F. oxysporum Schl. f. *Betae* (Stewart) Snyder *et* Hansen, *Amer. J. Bot.* **27**, 66 : 1940

A typo speciei haud distinguendum, vitium plantularum *Betae vulgaris* Linn. in America boreali efficiens.

Fusarium orthoceras App. *et* Wr. var. *Callistephi* (Beach) Padwick, *Indian J. agric. Sci.* **10**, 283 : 1940

Syn. *F. conglutinans* var. *majus* Wr. (*vide* Wollenweber and Reinking, *Die Fusarien*, p. 110)

F. conglutinans Wr. var. *Callistephi* Beach, *Michigan Acad. Sci. Rept.* **10**, 297 : 1918

F. oxysporum Schl. f. *Callistephi* (Beach) Snyder *et* Hansen, *Amer. J. Bot.* **27**, 66 : 1940

A typo speciei morphologice haud distinguendum ; vitium vasculare *Callistephi chinensis* Linn. in plerisque regionibus qua ea planta culta est, efficiens.

Fusarium orthoceras App. et Wr. var. *Ciceri*, var. nov.

A typo speciei morphologice haud distinguendum ; vitium vasculare *Ciceri arietini* Linn. in Delhi Karnalque, India, efficiens.

Culturae in Collectioni Culturarum Typicarum, Imperial Agricultural Research Institute, New Delhi, conditur ; preparationes typicae in Herb. Crypt. Ind. Orient. adsunt.

Fusarium udum Butler, *Mem. Dept. Agric. India* (*Bot. Ser.*) **2**, No. 9, 54 : 1910

Syn. *F. Butleri* Wr. *Phytopathology* **3**, 38 : 1913

F. uncinatum Wr. *Ann. Mycol.* **15**, 54 : 1917

F. vasinfectum Butler (nec Atk.) pro parte parasitica in radici *Cajani cajan* (L.) Millsp., *Agric. J. India* **21**, 273 : 1926 ; Butler and Bibsy, '*Fungi of India*', *Sci. Monogr. No.* **1**, *Imp. Counc. Agric. Res.* p. 146: 1931.

F. vasinfectum Atk. f. *Cajani* Kulkarni, *Indian J. agric. Sci.* **4,** 994 : 1934

F. lateritium Nees var. *uncinatum* Wr., *Arb. biol. Reich.* (*Berl.*) **22**, 341 : 1938

Syn *F. oxysporum* Schl. f. *udum* (Butler) Snyder and Hansen, *Amer. J. Bot.* **27**, 66 : 1940

Lectotypus in Herb. Crypt. Ind. Orient. Imp. Agric. Res. Institute, New Delhi indicatus est. Culurae in Collectioni Culturarum typicarum, Imp. Agric. Res. Institute, New Delhi, conditur.

Fusarium udum Butler var. *Crotalariae* (Kulkarni) Comb. nov.

Syn. *F. vasinfectum* Atk. pro parte parasitica in radici *Crotalariae junceae* Briant and Martyn, *Trop. Agric., Trin.* **6** 259 : 1929 ; Uppal, Patel and Kamat, *Dept. Agric. Bombay Bull.* **176**, 31 : 1935

F. vasinfectum Atk. f. *Crotalariae* Kulkarni, *Indian J. agric. Sci.* **4**, 994 : 1934

A typo speciei morphologice haud distinguendum ; vitium vasculare *Crotalariae junceae* Linn., haud *Cajani cajan* efficiens. Culturae in Collectioni Culturarum Typicarum Imp. Agric. Res. Institute, New Delhi, conditur ; preparationes in Herb. Crypt. Ind. Orient.

Summary

1. The history of the division of species of *Fusarium* into sections is outlined in relation to sections Elegans, Lateritium and Liseola.

2. It is shown that the present conception of the sections Elegans, Lateritium and Liseola does not agree with the original descriptions ; Elegans was split up into two sections, one retaining the original name and the other being given the new name Liseola.

3. It is as difficult to place borderline members of the three sections in the correct section as it is to identify correctly the species within a section.

4. Snyder and Hansen [1940] assume that, whereas the so-called speices within the section Elegans (and similarly in other sections) must be regarded as one species, the major grouping into sections in Wollenweber's system and the original description of the section Elegans are acceptable. It is shown that this assumption is contrary to the facts as clearly indicated, firstly by careful consideration of the way in which the sections Elegans, Lateritium and Liseola were built up and described, and secondly by the existence of intermediate forms.

5. It is concluded that although the work of Snyder and Hansen [1940] and Hansen and Smith [1932, 1938] must eventually influence classification within the genus, proper revision can only result from the combined efforts of workers in a position to study the various *Fusaria* in their natural habitat. The ultimate classification will have to give sufficient weight to ecological factors and geographical distribution.

6. Nomenclatural changes proposed up to the present are summarized.

REFERENCES

Butler, E. J. (1910). *Mem. Dept. Agric. India* (*Bot. Ser.*) **2**, No. 9
Hansen. H. N. and Smith, R. E. (1932). *Phytopathology* **22**. 953-64
—————————— (1938). *Mycologia* **30**, 442-55
Hansford, C. G. (1940). *East Africa Agric. J.* **5**, 279-82
Huxley, J. (1940). Towards *the new systematics*, pp. 1-46 : Oxford, Clarendon Press
Mason, E. W. (1940). *Trans. Brit. Mycol. Soc.* **24**, 115-25

Padwick, G. W. (1940,1). *Indian J. agric. Sci.* **10**, 241-84
——— (1940,2). *Indian J. agric. Sci.* **10**, 863-78
Snyder, W. C. and Hansen. H. N. (1940). *Amer. J. Bot.* **27**, 64-7
Subramaniam, L. S. and Chona, B. L. (1938). *Indian J. agric. Sci.* **8**, 189-90
Thom, C. (1940). *Report of Proceedings, Third International Congress for Microbiology, New York*, 1939, p. 187 : New York, International Association of Microbiologists 1940 (Seen in *Rev. Appl. Mycol.* **19**, 555-6 : 1940)
Turrill, W. B. (1938). *Biol. Rev.* **13**, 342-73
Wollenweber, H. W. (1913). *Phytopathology* **3**, 24-50
——— (1917) . *Ann. Mycol. (Berl.)* **15**, 1-56
——— (1918). *Ber. Deut. Bot. Gesell.* **35**, 732-42
——— (1938). *Arb. Biol. Reichsanst.* **22**, 339-47
Wollenweber, H. W. and Reinking, O. A. (1925). *Phytopathology* **15**, 155-69
——— (1935). *Die Fusarien* : Berlin, Paul Parey
Wollenweber, H. W.; Sherbackoff, C. D.; Reinking, O. A., Johann, Helen and Baile, Alice A. (1925). *J. agric. Res.* **30**, 833-43

STUDIES IN INDIAN CEREAL SMUTS

*II. VARIETAL RESISTANCE OF INDIAN AND OTHER WHEATS TO LOOSE SMUT

BY

B. B. MUNDKUR AND B. P. PAL

Imperial Agricultural Research Institute, New Delhi

(Received for publication on 14 January 1941)

(With Plate XXXVI and one text-figure)

IN a previous paper [Pal and Mundkur, 1939], we have outlined the principles which have been followed in developing cereal varieties resistant to smuts. Our efforts to discover varieties of wheat resistant to loose smut are reported in the present communication.

Loose smut of wheat caused by *Ustilago Tritici* (Pers.) Rostrup occurs wherever wheat is grown in India ; the intensity with which it manifests itself and the damage it causes vary with the locality. In the Punjab, Sind and the United Provinces this smut is known to cause considerable damage, and cases are by no means rare where nearly a quarter of the crop has been ruined. Loose smut is an internally seed-borne disease and its control by the external application of fungicidal treatments is not therefore possible. This internal mycelium in its dormant state resists attempts aimed at its destruction but becomes vulnerable to attack after germination. The seed is therefore soaked for four hours in water at a temperature of 26-27°C. and the soaked seed is then transferred to warmer water at 53-54°C., for about ten minutes. Pre-soaking induces the germination of the mycelium in the presence of moisture and the higher temperature kills it. The method is, however, attended by considerable risk as the temperature lethal to the mycelium is only sligthly lower than that which is lethal to the germinating seed itself.

The safest method of controlling loose smut is therefore by the development of varieties that resist the disease, and experience with the Imperial Pusa wheats has shown that among them are varieties which, under field conditions, show considerable resistance. To what extent such resistance is due to genetically determined factors which these varieties possess and how far they are cases of mere disease escape has, however, remained unknown. These investigations were therefore undertaken with a view to obtaining this knowledge.

METHODS

The method employed for infecting wheat heads with a suspension of spores *in vacuo* was the one designed by Moore [1936] and recently re-described by Oort [1939]. The apparatus consists of a glass tube, called the

*The first article of the series was published in the *Proceedings of the Indian Academy of Sciences* 9, pp. 267-70 : 1939

inoculation chamber, about 9 inches long and 1·25 inches in diameter. The bottom end of this chamber is fitted with a rubber stopper in which a slit and a hole are made ; a glass tube passes through the hole and is connected by means of rubber tubing to a flask containing a suspension of spores (one gram per litre of water). The heads are inserted into the chamber through the slit and sealed with plasticine to prevent the leakage of air. The top of the chamber is closed with another tightly fitting stopper, through which also passes a glass tube by means of which the inoculation chamber is connected with an exhaust pump. While inserting the wheat heads in the chamber and at the time of manipulating the apparatus, great care has to be exercised so as not to break the culms. The flask containing the spore suspension is placed on the ground, while the inoculation chamber and the exhaust pump are held in the hand. A Mohr pinch-cock, inserted in the rubber tubing leading to the flask, serves to close the access to the flask at will.

Wheat heads in the mid-anthesis stage are then selected, placed between the slit in the stopper and this stopper inserted in its proper place (Fig. 1). The flask containing the spore suspension is then connected to the inoculation chamber but the pinch-cock is kept closed. The top of the chamber is connected to the exhaust pump and about eight to ten pump-strokes are given to exhaust the chamber. The pinch-cock below is then opened when the spore suspension rushes into the inoculation chamber. A few more strokes are then given and the suspension held in the chamber for a minute, after which the pressure is released. The infected heads are tagged and covered with water-proof paper bags which help in creating a moist atmosphere for some time.

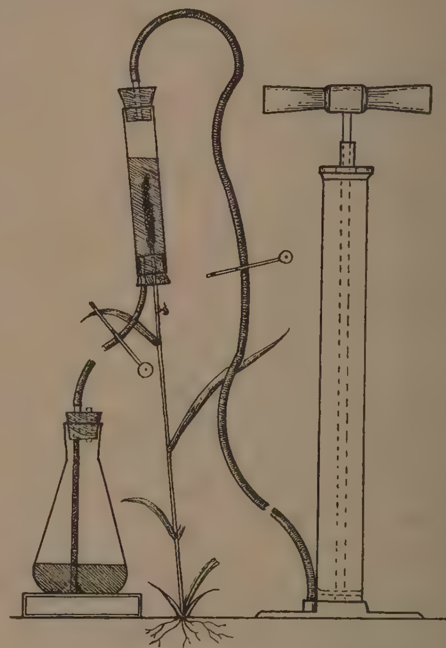


Fig. 1. Moore's method of infecting wheat ears with spores of loose smut

Selecting heads which are of proper maturity and at the correct stage of anthesis takes time, but if two or three heads of the same variety and at the same stage of anthesis are near each other, then all of them can be inserted at the same time into the chamber. About 40–50 heads can be infected in an hour in this manner. The spore suspension must, however, be changed when heads of a different variety have to be infected.

Wheat cultures are sown in single progeny rows, keeping one foot between the plants and 1½ ft. between the rows. This permits free access to the plants without the risk of damaging them.

When mature, the infected heads are individually harvested and threshed. Seeds from single heads are sown in separate rows during the next year. At the time of counting the diseased plants, those that show even a single smutted tiller or partially infected heads are classified as diseased. Heads from plants that are absolutely free from smut are utilized for re infection for the subsequent year's trials.

MATERIALS

The smut used in these experiments was collected at Pusa in January 1937. This collection or its descendants have been used throughout these tests. As physiologic races of loose smut are known to occur in other parts of the world and may occur in India also, care was taken to see that there was no mixture of smuts at any time.

The wheat seeds used in these investigations were from selfed heads and were pure for all the morphological characters.

The first season's trials were conducted at Pusa in 1936-1937 ; the later trials were carried out in the Botanical Section plots at New Delhi.

EXPERIMENTAL

1936-37.—The investigation was started with 40 varieties. They were sown on October 27, 1936, in a secluded plot. The growth of the plants was fair to good. The artificial infection of the heads began on 1st February 1937 and continued for about ten days. Ten to fifteen heads of each variety were infected. Harvesting was done in April, each head being placed in a separate envelope.

1937-38.—The infected seed was sown in single progeny rows on 16th and 17th November 1937. The plants grew quite well and the smut appeared on the 14th February 1938. Plants showing smut were immediately uprooted and a careful record of such plants was kept. The total number of plants per variety, the number that became smutted and per cent smut in each variety are given in Table I.

From the results in Table I it will be noted that the varieties IP 114, IP124 and Federation (all the four stocks) were resistant to the disease, while IP121 was only 0·4 per cent susceptible. Seven varieties, viz. IP 120, IP122, IP123, IP125, Punjab C 499 and Cawnpore 13 had 9·7—20·6 per cent susceptibility, but the rest were highly susceptible. The high percentage of smut infection obtained in these varieties indicated that the method of infecting the seed was very efficient.

Wheat heads from plants that had shown no smut were selected for the 1938-39 trials and 46 additional varieties were included in the tests. These were infected with smut in the usual manner.

1938-39.—Infected seed was sown on 12th and 13th November 1938. The plants made good growth and smut appeared in the first week of February following. As in the previous year, partially and fully attacked plants were uprooted and a record of smutted plants was kept. The results obtained during this season are given in Table II.

TABLE I

Total number of plants per variety, number of smutted plants and percentage of smutted plants in wheat varieties infected in 1936-37

Serial No.	Variety	Total No. of plants	Number of smutted plants	Percentage of smutted plants
1	Imperial Pusa 4	294	68	23·0
2	,, ,, 6	193	47	24·3
3	,, ,, 12	214	125	58·4
4	,, ,, 52	156	48	30·8
5	,, ,, 80-5	131	40	30·5
6	,, ,, 101	198	160	80·8
7	,, ,, 111	157	46	29·2
8	,, ,, 114	156	0	0
9	,, ,, 120	164	16	9·7
10	,, ,, 121	219	1	0·4
11	,, ,, 122	122	24	20·6
12	,, ,, 123	183	21	11·4
13	,, ,, 124	187	0	0
14	,, ,, 125	91	13	14·2
15	,, ,, 126	91	18	19·7
16	Jaipur	107	36	33·6
17	Muzaffarnagar	110	39	35·4
18	Muzaffarpur White	140	79	56·4
19	,, Red	112	36	32·1
20	Lal Kesar Wali	82	27	32·9
21	Punjab 8A	243	34	13·9
22	,, 9D	143	61	45·5
23	,, C409	155	44	28·3
24	,, C499	149	25	16·7
25	,, C518	158	83	52·5
26	,, C591	146	110	75·3
27	Cawnpore 13	256	43	15·1
28	Federation (new stock)	250	0	0
29	,, (old, red-glumed)	215	0	0
30	,, (old, white-glumed)	115	0	0
31	,, (from Tarnab)	195	0	0
32	Bihar 9	93	60	64·5
33	,, 18	132	56	42·4
34	,, 19	181	49	27·0
35	,, 20	110	71	64·5
36	,, 21	119	62	52·1
37	,, 22	97	52	53·6
38	,, 26	78	48	61·5
39	,, 27	118	74	62·7
40	,, 29	87	31	35·6

TABLE II

Total number of plants per variety, number of smutted plants and percentage of smutted plants in wheat varieties infected in 1937-38

Serial No.	Variety	Total No. of plants	Number of smutted plants	Percentage of smutted plants
1	Imperial Pusa 4	186	172	92·4
2	,, ,, 6	67	63	94·0
3	,, ,, 12	179	169	94·4
4	,, ,, 52	211	194	91·8
5	,, ,, 80-5	191	44	23·0
6	,, ,, 101	81	74	91·3
7	,, ,, 111	127	126	100·0
8	,, ,, 114	141	0	0
9	,, ,, 120	75	0	0
10	,, ,, 121	117	0	0
11	,, ,, 122	121	0	0
12	,, ,, 123	198	181	91·4
13	,, ,, 124	87	0	0
14	,, ,, 125	302	195	64·5
15	,, ,, 126	196	166	84·9
16	Jaipur	72	56	77·8
17	Muzaffarnagar	16	13	81·3
18	Muzaffarpur White . . .	65	60	92·3
19	,, Red . . .	75	60	80·0
20	Lal Kesar Wali	67	59	88·3
21	Punjab 8A	216	201	93·1
22	,, 9D	231	230	100·0
23	,, C409	158	152	96·2
24	,, C499	222	161	72·5

TABLE II—*contd.*

Serial No.	Variety	Total No. of plants	Number of smutted plants	Percentage of smutted plants
25	,, C518	140	135	96·4
26	,, C591	165	165	100·0
27	Cawnpore 13	229	193	84·3
28	Federation (new stock)	149	67	45·0
29	,, (old, red-glumed)	119	0	0
30	,, (old, white-glumed)	42	0	0
31	,, (from Tarnab)	127	0	0
32	Bihar 9	42	37	86·5
33	,, 18	82	72	95·1
34	,, 19	72	69	95·8
35	,, 20	75	73	97·6
36	,, 21	76	76	100·0
37	,, 22	59	59	100·0
38	,, 26	48	28	58·3
39	,, 27	75	68	90·6
40	,, 29	38	30	78·8
41	Imperial Pusa 90	45	33	73·3
42	,, ,, 163-3	35	0	0
43	,, ,, 163-4	43	0	0
44	,, ,, 165	210	0	0
45	111-2-3	63	55	87·3
46	114-2-4	75	65	86·6
47	111-2-6	64	59	92·1
48	111-2-7	68	60	88·2
49	111-2-8	78	29	37·1

TABLE II—*contd.*

Serial No.	Variety	Total No. of plants	Number of smutted plants	Percentage of smutted plants
50	111-2-9	48	34	70·8
51	114-1-47	59	37	62·6
52	114-1-53	48	19	39·6
53	114-3-2	64	47	73·4
54	54-1-1-5	69	62	90·0
55	86-1-1-1	60	58	96·6
56	95-1-1-7	49	0	0
57	54-2-1-1-9	62	54	87·0
58	13-1-5-10E	44	3	6·8
59	13-1-5-10L	51	21	41·1
60	64-1-1-10	82	46	56·8
61	3-1-2-6	78	46	58·8
62	CPH 47	80	65	81·5
63	AT 38	48	45	93·6
64	HSW	67	51	76·1
65	Chinese White	56	0	0
66	*T. sphaerococcum*	71	19	26·7
67	Flora	24	0	0
68	Gular	77	62	80·5
69	Geerlying	71	47	66·2
70	Sword	71	0	0
71	Khapli	73	0	0
72	Garnet	77	69	89·6
73	Reward	85	31	36·4
74	,,	62	30	48·3

TABLE II—*concld.*

Serial No.	Variety	Total No. of plants	Number of smutted plants	Percentage of smutted plants
75	Rajah	52	3	5·7
76	Ranee	68	48	70·7
79	Igachikugo	79	0	0
80	Eshimashiuraki	14	0	0
81	Nawaba	57	10	17·6
82	Ford	38	0	0
83	Dundee	60	0	0
84	Baringa	58	36	62·0
85	Firbank	37	23	62·1
89	Gullen	50	40	80·0
91	Ideal	72	13	18·5
97	Florence	20	0	0

It will again be noted from the results recorded in Table II that the varieties IP114, IP124 and Federation (three stocks) remained highly resistant. Selections for high resistance made in the previous year in the varieties IP 120, IP 121, and IP 122 were also successful, but the other selections proved failures. One stock of Federation which failed to take infection the previous year proved to be a susceptible variety. Among the newly included varieties, IP 163-3, IP163-4, IP165, 95-1-1-7, Chinese white, Flora, Sword, Khapli, Igachikugo, Eshimashiuraki, Ford, Dundee and Florence showed promise. Among others that showed less than 10 per cent susceptibility were 13-1-5-10E and Rajah. The rest were highly susceptible.

Heads from healthy plants were again infected for trial in 1939-40 and three additional varieties were added for the determination of their relative susceptibility to loose smut.

1939-40.—The increase in work made it necessary to exercise discrimination and eliminate certain varieties so as to keep the work within bounds. In making this elimination two things were prominently kept in mind : (1) the degree of susceptibility of a variety, and (2) its economic importance. If a variety was highly susceptible but economically important,

it was retained in the hope that further selection within such a variety might furnish resistant individuals. If a variety, on the other hand, was highly resistant or immune but otherwise unimportant or undesirable, it was retained with the object of using it as a parent in hybridization work.

Sowing was done in the third week of November and the plants made good growth. Smut appeared in the second week of February 1940 and smutted plants were uprooted as in previous years. The results are given in Table III.

TABLE III

Total number of plants per variety, number of diseased plants and percentage of smutted plants in wheat varieties infected in 1938-39

Serial No.	Variety	Total No. of plants	Number of smutted plants	Percentage of smutted plants
	Varieties immune in previous two seasons			
8	Imperial Pusa 114 . . .	279	0	0
13	,, ,, 124 . . .	342	0	0
29	Federation (old, red-glumed) . .	373	0	0
30	,, (old, white-glumed) .	454	0	0
31	,, (from Tarnab) . .	593	0	0
	Varieties immune in past one season			
44	Imperial Pusa 165 . . .	234	41	17·4
56	95-1-1-7	327	0	0
65	Chinese white	336	4	1·1
67	Flora	222	1	0·4
70	Sword	261	0	0
71	Khapli	183	0	0
78	Free Gallipolli	223	0	0
79	Igachikugo	290	0	0
80	Eshimashiuraki	187	0	0
82	Ford	310	1	3
83	Dundee	317	0	0
97	Florence	307	0	0

TABLE III—*contd.*

Serial No.	Variety	Total No. of plants	Number of smutted plants	Percentage of smutted plants
	Varieties highly resistant in past seasons			
9	Imperial Pusa 120 . . .	210	0	0
10	,, ,, 121 . . .	398	14	4·5
58	13-1-5-10E	328	31	9·4
	Varieties highly susceptible in past seasons			
1	Imperial Pusa 4 . . .	378	257	67·9
4	,, ,, 52 . . .	311	195	62·7
5	,, ,, 80-5 . . .	321	238	74·1
7	,, ,, 111 . . .	309	118	38·1
14	,, ,, 125 . . .	322	48	14·9
21	Punjab 8A	374	184	49·1
25	,, C518	357	237	66·3
27	Cawnpore 13	415	144	33·7
	Newly included varieties			
98	C5271-W1	256	48	18·7
99	Imperial Pusa 100 . . .	268	182	67·9
100	114-1-8	321	0	0
	Controls (fresh seed)			
6	Imperial Pusa 101 . . .	299	271	90·6
26	Punjab C591	288	221	76·7
35	Bihar 20	417	400	96·5

The varieties IP114, IP124 and Federation (three stocks) which were uninfected with loose smut in the first year continued to be so. Imperial Pusa 165 which failed to take infection in 1938-39 showed 17·4 per cent infection. The nature of smut attack in this variety was rather peculiar. Not all the ears in a plant were infected and the ears themselves were only partially attacked. Smutted heads with different degrees of infection are shown in Plate XXXVI. For the present this variety has been classified among the highly resistant and future selections may give completely resistant individuals. Selections made in IP120 and IP121 in 1937-38 continued to maintain their resistance, the former having shown no infection by

Smutted heads of IP 165 wheat showing different degrees of infection

smut in two successive seasons. Most of the others have continued to maintain their resistance likewise. Among the new varieties tested during the year, 114-1-8 seemed to be resistant, while C 5271-W1 may yield resistant selections. The highly susceptible varieties and the controls grown from new seed of these varieties showed, as expected, high susceptibility to smut.

Desirable plants free from smut have, in all the above varieties, been re-infected and 32 additional varieties have been also included for noting their reaction to loose smut. In future it is proposed to include wheat varieties developed by the provincial wheat breeders if time and facilities permit.

Discussion

The four-year trials reported in this paper show that in India, as elsewhere, varieties of wheat highly resistant to, or immune from, loose smut can be successfully bred. Although many of the improved varieties evolved in this country are susceptible, a few of them—notably IP114—are very highly resistant or even immune.

It is interesting to note that these results, carried out under strictly controlled conditions, are in agreement with field experience regarding the resistance or susceptibility of the varieties, wherever such data are available for comparison. Thus, it was already known that under field conditions IP 114 is invariably free from loose smut. A striking example of its freedom from this disease was afforded in 1933-34 at Karnal. The area under this wheat was surrounded every year by a larger area under Punjab 8A which in that and the previous seasons had shown high incidence ; IP114, however, remained uninfected. A few smutted plants observed in the fields were found upon examination to be rogue plants of a different variety. It is also a matter of common knowledge, for example, that Punjab C 591 is highly susceptible to loose smut. In our tests likewise this variety proved to be exceedingly susceptible and we use it as a susceptible 'control'.

A noteworthy fact that needs to be mentioned is that both the immune Indian varieties (and some of the highly resistant ones) are derived from the Australian variety Federation which itself has proved to be immune in these tests. Imperial Pusa 114, for instance, arose as a natural cross in a field of Federation growing at the Imperial Agricultural Research Institute at Pusa. The immune IP124, and the resistant varieties IP120, IP121, IP122 and IP 165 are also of hybrid origin, being the progeny of crosses between Federation and Indian wheat varieties. Evidently genetic factors for high resistance have been transmitted to these hybrids from the Federation parent.

The tests have further indicated that it is possible sometimes to obtain resistant strains by selection within a partially susceptible variety and that varieties which are homozygous for the morphological characters are not necessarily so for smut resistance. The results also show that seasonal factors may influence the degree of infection and a variety which is found to be apparently immune in one season may prove to be slightly or even moderately susceptible in subsequent seasons. In spite of the successful method of infecting wheat heads, varieties which show more than 20 per cent susceptibility should, to be on the safe side, be classified as susceptible, in breeding work.

In any investigation which involves the selection of varieties resistant to a disease, the question of physiological specialization of the causal organism should not be lost sight of. Preliminary work has already shown that such physiologic races of loose smut exist in India and work is in progress to determine their number and distribution.

SUMMARY

Loose smut of wheat caused by *Ustilago Tritici* (Pers.) Rostrup occurs wherever wheat is grown. It can be controlled by the so-called hot water treatment, but this is not free from the hazard of impairing seed viability. The safest and the best method is the growing of smut-resistant varieties.

2. Nearly 100 varieties of wheat have been tested for their reaction to smut. For this purpose each variety was artificially infected using the method devised by Moore.

3. The results show that a few varieties including IP 114 are immune, a large number, including IP 120 and IP 165, are resistant and the majority are susceptible.

4. Selection within several partially susceptible varieties with a view to finding highly resistant or immune segregates was successful. A similar attempt in the case of highly susceptible but economically important varieties proved, however, a failure.

ACKNOWLEDGEMENTS

We wish to thank Dr G. Watts Padwick and Dr S. Ramanujam for critically reading through the manuscript of this paper. We also wish to place on record our appreciation of the help given in these investigations by Messrs. C. B. Sahaya, K. M. Dutt and H. R. Khan, Fieldmen in the Mycological and Botanical Sections.

REFERENCES

Moore, M. B. (1936). *Phytopathology* **26**, 397-400

Oort, A. J. P. (1939). *Phytopathology* **29**, 717-28

Pal, B. P. and Mundkur, B. B. (1939). *Proc. Indian Acad. Sci.* **9**, 267-70

STUDIES IN INDIAN CEREAL SMUTS

III. VARIETAL RESISTANCE OF INDIAN AND OTHER WHEATS TO FLAG SMUT

BY

B. P. PAL

AND

B. B. MUNDKUR

Imperial Agricultural Research Institute, New Delhi

(Received for publication on 14 January 1941)

NOT much attention has been given in India to the disease in wheat caused by *Urocystis Tritici* Koernicke and commonly known as flag smut. A short account of it was given by Butler [1918] who first discovered it at Lyallpur in the Punjab. Since that time it has been found to be fairly widespread in the Punjab and the North-West Frontier Province. Plants attacked by flag smut have recently been received from Baluchistan where it is reported to be doing much damage to the wheat crop. Flag smut was found to be fairly common in Southern Afghanistan by Mundkur [1940].

How long the disease has been prevalent in India, is not possible to say with any certainty. The fact that it is not very extensively spread probably indicates recent introduction from some other country, but its absence in the United Provinces, Bihar, Central Provinces, Sind and Bombay may also be due to these areas being relatively warmer in winter than the Punjab and the Frontier Province. Thus even though conditions for the rapid dissemination of the causal organism which is seed-borne exist, favourable conditions for its development do not seem to occur widely, excepting in the restricted areas stated above.

Flag smut can cause considerable damage to the wheat crop when it appears in epidemic proportions, and in places where it has firmly established itself such epiphytotics are not rare. Losses are principally due to decreased yields rather than to the actual deaths of the plants ; the number of badly infected plants and those that die even before the heads have formed is indeed small, but if a large number of culms per plant is infected without actually killing the plants, then the decrease in the yield of grain is quite appreciable. Flag smut has sometimes been found in almost all the plants in a field, but the number of culms affected has been small so that the actual loss of yield was not great. On the other hand, the reverse would have been the case if a heavy infection of the culms had also taken place.

There is, however, another kind of loss which flag smut infection may cause. It has been noted that seed harvested from flag smutted plants is not all viable. Actual germination tests carried out in the Mycological Section with such seed have shown that up to 63·7 per cent of the seed is non-viable and does not germinate. Such seed is much shrivelled and does not possess the bright appearance of good seed.

In the field flag smut manifests itself about four to five weeks after sowing and some time before the heads begin to emerge from the boots. The disease is characterized by the development of more or less straight, yellowish white or grey stripes on the leaves ; these stripes which are the sori of the smut vary from a few mm. in length to frequently the whole length of the leaf. They soon change colour and ultimately turn black and burst, exposing masses of dark-brown spores. Sori may be found on the lower glumes of the flowers and even on the awns. Affected plants are usually stunted, the leaves are rolled and the culms twisted, giving the plants a mis-shapen appearance.

Investigations conducted by McAlpine [1910], Hamblin [1921], Tisdale, Dunegan and Leighty [1923], Yu, Chen and Hwang [1933] and others have shown that flag smut may be disseminated by infected seed, by dung of animals fed on infected wheat hay, and by farm implements used during harvesting and threshing. It is thus both seed- and soil-borne and its control by the use of fungicidal treatments is consequently not always successful. In Illinois, Tisdale, Dunegan and Leighty [1923] reported as a result of an extensive trial that wheat varieties immune, highly resistant or susceptible to flag smut exist. Immune or highly resistant wheats have also been reported from Australia, where the disease is very destructive, by Shelton [1924], Carne and Limbourn [1927], Morwood [1929], Pridham and Dwyer [1930] and others and from China by Yu, Chen and Hwang [1933]. The problem of developing flag-smut resistant wheat varieties either by selection or by hybridization has received considerable attention in the Mycological and Botanical Sections of the Imperial Agricultural Research Institute, New Delhi, during the past three years and the results so far obtained are presented in this paper.

Materials and methods

Spores of *Urocystis Tritici* for infection were collected in April 1937 at Ferozepur, Punjab. The infected leaves were ground into a fine powder which was placed in an excess quantity of water in a large beaker. The mixture was stirred vigorously for a quarter of an hour in order to release the spores from the sori into the water. The mixture was then allowed to settle down when the residue of the leaves floated on top, while the spores settled down below. A large quantity of the spores was collected in this manner, dried thoroughly, and stored in glass vials in the refrigerator. The residue of the leaves was spread in the field where the trials were later to be conducted.

Selfed seed of 97 varieties of wheat was used in these tests. Two days prior to sowing, the seed of each variety was smeared quite thoroughly with the spores and placed in separate petri dishes. Moist sand was then put in the dishes and the dishes were kept in a cool place. On the third day the seed started to germinate. The seedlings were carefully removed, again dipped in a suspension of spores and sown in single progeny rows. The spores themselves had been soaked in water for four days before they were used for smearing the seed. Experiments reported by Noble [1924] have shown that such a pre-soaking treatment of the spores is necessary before they can germinate abundantly.

When flag smut began to manifest itself, the infected plants were uprooted and a careful count of such plants was kept. At the end of the season,

five plants that were quite free from flag smut and which showed the typical characters of that variety were selected in each variety.

It will be noted that many wheats were not tested throughout the three years of the experiment. They were discarded not only because of their high susceptibility to flag smut but also because they were of no value from the economic point of view. Some of the susceptible but economically valuable varities were, however, retained in the hope that it would be possible to obtain, within them, less susceptible individuals by further selection.

Experimental

The results obtained during the past three years with the 97 wheat varieties are given in Table I.

TABLE I

Reaction of Indian and other wheats to flag smut

Serial No.	Variety	Percentage of smutted plants		
		1938	1939	1940
1	Imperial Pusa 4 . . .	1·0	0·48	1·5
2	,, ,, 6 . . .	37·0	21·0	..
3	,, ,, 12 . . .	17·6	9·5	18·1
4	,, ,, 52 . . .	30·2	19·3	35·6
5	,, ,, 80-5 . . .	0	6·2	5·5
6	,, ,, 101 . . .	51·7	15·0	..
7	,, ,, 111 . . .	0	0	0·5
8	,, ,, 114 . . .	36·2	18·1	24·3
9	,, ,, 120 . . .	34·4	12·4	37·5
10	,, ,, 121 . . .	30·1	15·6	..
11	,, ,, 122 . . .	29·3	25·0	..
12	,, ,, 123 . . .	26·7	10·1	..
13	,, ,, 124 . . .	23·6	6·5	..
14	,, ,, 125 . . .	42·7	9·1	30·7
15	,, ,, 126 . . .	31·2	17·1	..
16	Jaipur	25·6	12·0	..

TABLE I —*contd.*

Serial No.	Variety	Percentage of smutted plants		
		1938	1939	1940
17	Muzaffarnagar	61·6	12·2	..
18	Muzaffarpur White . . .	76·1	21·9	..
19	,, Red . . .	64·6	26·3	..
20	Lal Kesar Wali	6·6	12·8	..
21	Punjab 8A	35·1	7·2	25·0
22	,, 9D	62·5	24·5	..
23	,, C409	44·3	23·6	..
24	,, C499	31·7	9·4	..
25	,, C518	72·7	26·0	38·5
26	,, C591	15·7	8·3	12·5
27	Cawnpore 13	12·4	7·3	17·5
28	Federation (new stock) . .	18·3	6·4	..
29	,, (old, red-glumed) . .	64·7	12·8	..
30	,, (old, white-glumed) .	41·8	4·2	..
31	,, (from Tarnab) . .	56·9	3·4	..
32	Bihar 9	46·4	5·6	..
33	,, 18	63·4	23·0	..
34	,, 19	88·6	15·7	..
35	,, 20	67·9	14·6	..
36	,, 21	74·3	22·2	..
37	,, 22	76·9	28·5	..
38	,, 26	84·2	29·0	50·0
39	,, 27	80·5	25·0	..
40	,, 29	84·4	20·9	..
41	Imperial Pusa 90 . . .	47·0	25·0	..

TABLE I—*contd.*

Serial No.	Variety	Percentage of smutted plants		
		1938	1939	1940
42	Imperial Pusa 163-3	17·8	9·7	..
43	,, ,, 163-4	21·3	12·5	..
44	,, ,, 165	9·9	10·3	16·1
45	111-2-3	0	0	1·3
46	114-2-4	0	0	1·1
47	111-2-6	0	0	0
48	111-2-7	0	0·3	0·5
49	111-2-8	0	0	0
50	111-2-9	0	0·5	0
51	114-1-47	43·3	10·4	15·6
52	114-1-53	41·6	5·2	13·2
53	114-3-2	6·8	9·6	15·0
54	54-1-1-5	71·3	20·0	..
55	86-1-1-1	42·9	16·0	28·7
56	95-1-1-7	9·9	7·6	..
57	54-2-1-1-9	52·5	23·0	..
58	13-1-5-10E	55·1	3·2	..
59	13-1-5-10L	62·1	13·0	..
60	64-1-1-10	24·5	8·3	..
61	3-1-2-6.	36·4	6·8	..
62	CPH 47	40·9	16·4	..
63	AT 38	49·1	7·4	..
64	HSW	32·5	10·4	..
65	Chinese White	12·7	3·7	..
66	*T. sphaerococcum*	40·5	21·5	..

TABLE I—*contd.*

Serial No.	Variety	Percentage of smutted plants		
		1938	1939	1940
67	Flora	40·3	4·4	..
68	Gular	5·0	3·7	18·0
69	Geerlying	0	0	0
70	Sword	0	3·3	1·8
71	Khapli	4·0	2·0	..
72	Garnet	8·1	13·0	..
73	Reward	1·3	2·0	..
74	,,	0	0·8	..
75	Rajah	8·7	11·4	..
76	Ranee	1·2	0	..
77	Minister	0	2·4	..
78	Free Gallipolli	3·4	17·4	..
79	Igachikugo	0	0	0.4
80	Eshimashiuraki	8·9	7·7	..
81	Nawaba	0	3·7	..
82	Ford	3·3	7·4	..
83	Dundee	0	0	1·2
84	Baringa	0	0	1·8
85	Firbank	9·0	9·0	..
86	Gasta	26·1	34·3	..
87	Genoa	0	0	0·5
88	German	0	0	0
89	Gullen	0	1·6	..
90	Hornblende	0	0	0
91	Ideal	0	10·7	..

TABLE I—*concld.*

Serial No.	Variety	Percentage of smutted plants		
		1938	1939	1940
92	Jonathan	0	6·7	..
93	Mardi	1·5	0	..
94	Peragis	0	0	1·3
95	Stockman	0	0	0·5
96	Wandilla	1·6	1·4	..
97	Florence	0	1·7	..
98	C5271-W1	..	2·7	0·4
99	Imperial Pusa 100 . . .	..	3·8	..
100	114-1-8	..	14·6	31·8

DISCUSSION

The data given in Table I confirm the findings of other investigators that there are in existence wheat varieties which possess considerable resistance and even immunity to flag smut. The varieties 111-2-6, 111-2-8, 111-2-9, Geerlying, German and Hornblende throughout remained immune from flag smut, while IP 4, IP 111, 11-2-3, 111-2-4, Sword, Igachikugo, Dundee, Baringa, Genoa, Peragis, Florence and C 5271-W1 showed very high resistance, only 0·4-1·8 per cent of the plants succumbing to attack ; infection in these cases was moreover slight, a few culms only being mildly affected. It is possible that these varieties may give immune segregates on further selection.

Up to 76·1 per cent smut was registered in the susceptible varieties in 1937-38, but attack during the succeeding years was not high. The years 1938-39, and 1939-40 were characterized by drought and much less cold in the winter, and both these factors may have operated in keeping down smut attack. These results show in a vivid manner the influence which climatic factors exercise on the appearance of flag smut.

Flag smut is among the few diseases in which physiologic specialization of the causal organism has not yet been reported. But these investigations show that such physiologic races may exist. Pridham and Dwyer [1930] found the varieties Ranee and Florence to be susceptible under Australian conditions, while Baringa and Gullen were classified by them as moderately resistant. In the tests carried out at New Delhi all these four varieties showed only 1-2 per cent infection. The varieties Nawaba and Ford which Pridham and Dwyer [1930] classified as very highly resistant showed 3·7 and 7·4 per cent infection respectively, while their so-called resistant variety,

Firbank, showed 9 per cent attack. Presumably therefore the race of flag smut occurring in Australia is different from the one occurring in the Punjab. It is hoped that work now under way will show whether such races exist within India itself.

Summary

1. The flag smut disease of wheat caused by *Urocystis Tritici* is common in parts of the Punjab, the North-West Frontier Province, Baluchistan and also in southern Afghanistan. It is, however, not known from the other wheat-growing regions of India and it is possible that their relatively warmer winters do not favour the development of the disease.

2. Ninety-seven Indian and other varieties were tested over a period of three years for resistance to flag smut. The method used for infecting the seeds is described.

3. Six varieties were completely resistant to flag smut, while 14 varieties including IP 4 and IP 111 showed high resistance. The remaining varieties showed varying degrees of susceptibility.

4. Though physiological specialization in the flag smut fungus has not hitherto been reported, there is reason to suppose that the Indian strain of flag smut used in these studies is different from the one occurring in Australia.

Acknowledgements

We wish to thank Dr G. Watts Padwick for critically reading through the manuscript of this paper. We also wish to express our appreciation of the help given by Messrs M. Taslim, C. B. Sahaya, K. M. Dutt, and H. R. Khan of the Mycological and Botanical sections in these investigations.

REFERENCES

Butler, E. J. (1918). *Fungi and disease in plants* : Calcutta
Carne, W. M. and Limbourn, E. J. (1927). *J. Dep. Agric. W. Aust.* 2nd ser. **4**, 4-7
Hamblin, C. O. (1921). *Agric. Gaz. N. S. W.* **32**, 23
McAlpine, D. (1910). *Smuts of Australia* : Melbourne
Morwood, R. B. (1930). *Qd. agric. J.* **33**, 81-8
Mundkur, B. B. (1940). *Kew Bulletin* **7**, 285-8
Noble, R. J. (1924). *J. agric. Res.* **27**, 451-89
Pridham, J. T. and Dwyer, R. E. (1930). *Agric. Gaz. N. S. W.* **41**, 413-5
Shelton, J. P. (1924). *Agric. Gaz. N. S. W.* **35**, 336-8
Tisdale, W. H. ; Dunegan, G. S. and Leighty, C. E. (1923). *Bull. Illinois agric. Exp. Sta.* **242**, 511-37
Yu T. F. Chen, H. ; K. and Hwang, L. (1933). *Bull. Coll. Agric. and For. Nanking* **9** (n. s.), 1—18 ; also *Nanking J.* **3**, 217—34 (May 1933)

STUDIES IN INDIAN CEREAL SMUTS

IV. VARIETAL RESISTANCE OF INDIAN AND OTHER OATS TO SMUTS

BY

R. D. BOSE

AND

B. B. MUNDKUR

Imperial Agriculural Research Institute, New Delhi

(Received for publication on 14 January 1941)

THERE are only two fungous diseases of oats which affect the crop rather seriously in India, the covered smut and the loose smut. Of these the covered smut caused by *Ustilago Kolleri* Wille is the more predominant and widespread disease, while the loose smut for which *U. Avenae* (Pers.) Jens. is responsible, is of minor importance and seems to be restricted to certain areas in the Punjab and the United Provinces.

By the application of fungicidal treatments either in the form of dusts or as liquids for steeping the seed, both these smuts have been successfully controlled. Some years ago Mundkur and Khan [1934] showed that the dry spray method of applying formalin to smutty seed completely eliminates the disease. The treatment is now used in several oat-growing sections, its cheapness, the ease with which it can be applied and the complete control which it gives, having rendered it popular.

In the course of the work on breeding better oats by selection and by hybridization, it became apparent that there are varieties which under field conditions are not attacked by smut. Whether this apparent resistance of these varieties is due to genetically determined factors or whether they are mere disease escapes has remained, however, unknown. The result of the efforts made to determine this is reported in the present paper. Owing to its greater importance, the covered smut has naturally received greater attention.

The causal organism of covered smut

Usilago Kolleri, the causal organism of covered smut, is externally seed-borne and the disease caused by it is systematic. Reed and Faris [1924] have shown that the infection of the host takes place in the seedling stage, usually through the coleoptile while it is still 2 cm. or less in length. The mycelium very soon makes its way to the embryonic tissues of the oat plant and continues to grow in intimate relation with it for several weeks. At the time of flowering and the development of the ovule, the mycelium grows rapidly and passes into the spore-forming stage, resulting in the replacement of the floral parts by the dusty masses of black spores. In the covered smut the glumes are left somewhat intact, but in the loose smut they are completely destroyed.

Investigations by Reed and Faris [1924] have clearly established that there is a definite connection between certain factors of environment and infection of the host by the covered smut. A temperature of 20°C., a moisture content of about 20 per cent of the water-holding capacity of the soil and neutral reaction have been determined to be most favourable for the initial penetration by the fungus into the host. Once the successful infection has taken place, it is believed that the later development of the smut is not profoundly conditioned by environmental factors.

Longevity of the spores of *U. Kolleri*

The spores of several species of the family Ustilaginaceae are known to live for several years if stored under proper conditions of temperature and relative humidity. Sampson [1928] found viable spores of *U. Kolleri* in a collection which was 5½ years old and Sobel [1933] reports that even 13½ years old spores of this smut are viable. Fischer [1936] noted that the spores of covered smut from herbarium specimens that were four years old had not lost their viability, but older ones, however, had.

Strangely enough and contrary to expectations, under Pusa and New Delhi conditions, the spores of *U. Kolleri* begin to lose their viability very quickly after the fourth month. Mature smutted ears which had been collected during harvest and which had been adequately air-dried, have been stored in a dry place in the laboratory and also in a refrigerator registering about 8°C. throughout the summer ; spores have been screened out of the sori, air-dried, placed in dry test-tubes, sealed, and then placed both in a cool place in the laboratory and in the refrigerator. Attempts have been made to germinate such spores in rain water, in a 2 per cent sucrose solution and a 3 per cent infusion of oat pales, suggested by Diehl [1925]. Negative results have been obtained in all cases in the germination of the spores that were over four months old. Ultimately it was discovered that if smutted ears are wrapped in blotting paper and stored at a temperature of 12°C., the viability of a majority of the spores can be prolonged, at least until sowing time.

What the precise factors are that operate in rendering the spores non-viable has not so far been possible to ascertain. But spores adhering to the pericarp of the stored seed do not seem to lose their viability to an appreciable extent, even though no special storage precautions are taken, for covered smut appears in the fields year after year.

Materials

Spores of covered smut were collected in 1931 from variety BS 1 (now called IP 1) in the Agronomist's plots at Pusa. The spores were 100 per cent viable at the time of collection, but it was later found that 92 per cent of the spores had lost their viability at the time when oats were sown. Only a few infected ears became available, therefore, at harvest time for the subsequent year's trials.

Seeds used in these experiments were from selfed plants and consisted of standard oat varieties, recent selections, promising hybrids and acclimatized exotic varieties. As most of the latter seemed to be highly resistant to covered smut under Pusa conditions, several hybrids between these and the more susceptible Indian oats were made and tested.

Methods

Prior to sowing, the seeds of all the varieties were dehulled, the investigations by Reed and Faris [1924] and Reed [1924] having shown that this ensures infection by the smut. Four days before the actual date of sowing, the dehulled seeds were wetted and smeared thickly with spores, placed in petri dishes and covered with sand of proper moisture content. The dishes were then placed in an incubator at 20°C. The seedlings were about 2-3 cm. in length on the fourth day when they were transplanted in single progeny rows in the field.

The disease manifested itself as soon as ear formation had started. During harvest, counts of healthy and smutted plants were separately taken and the latter were also uprooted. Representative plants showing the typical characters of the variety were selected from among the healthy plants, for the next year's trials.

The trials were conducted at Pusa from 1932-33 to 1936-37 and at New Delhi from 1937-38 to 1938-39. Because of the failure of the smut spores to germinate consistently, results for the seasons 1933-34, 1934-35 and 1937-38 are not available.

Results of tests with covered smut

The results obtained with the Imperial Pusa and the exotic varieties to determine their reaction to covered smut are given in Table I.

It will be noted from the results recorded in Table I that in 1932-33 almost all the exotic varieties showed little or no infection to covered smut, whereas in 1935-36 only seven exotic varieties, Kinwada S 10, Nebraska 21, Iowar 670, Gopher and Kanota and two Pusa hybrids, viz. I-207-95 and VII-408, showed complete resistance. Only one other variety, Orion, showed substantially less smut, its susceptibility being 7·6 per cent. In 1936-37 the seed of Iowar 670 which had shown immunity from smut did not germinate and was not therefore available for trial, but of the other immune varieties, Kinwada S 10, Nebraska 21, Gopher and IP hybrid I-207-95 were alone free from infection, varieties Kanota and IP hybrid VII-408 showing 0·5 and 0·7 per cent infection, respectively. Selections made in Abundance and Orion oats showed promise, the former being free from disease and the latter having only 3·4 per cent infection. In 1938-39 Abundance, Gopher and IP hybrid VII-408 were free from infection, IP hybrid I-207-95 had 0·7 per cent ; the seed of Orion and Kanota did not germinate and the mode of their reaction to smut during that year is not available.

It should be noted that the exotics, Scotch Potato, Abundance, Iowa 103 and Kinwada S10, belonging to the species *Avena sativa* L. are immune, resistant or susceptible to this race of covered smut under Indian conditions. Imperial Pusa 1, 2 and 4 which are Indian varieties belong, however, to *Avena sterilis* L. var. *culta* and are without exception highly susceptible. Hybrids between the various Indian and foreign varieties that have so far been studied and the results of which are given in Table I show a rather wide range of susceptibility and resistance to covered smut and demonstrate that both the *sativa* and the *sterilis* groups from the same crosses are equally susceptible,

TABLE I

Reaction of Indian and exotic oats to covered smut

Identity No.	Variety		Type of base	Percentage reaction to smut				
				Seeds infected without hulling	Seeds infected after hulling			
				1932-33	1932-33	1935-36	1936-37	1938-39
4	Scotch Potato		*Sativa*	0·9	1·2	30·2	12·9	...
5	Abundance		,,	1·2	4·3	35·8	0	0
6	Orion		,,	0	1·1	7·6	3·4	...
7	Kinwada S 10		,,	0	0	0	0	15·4
8	Nebraska 21		,,	0	0	0	0	38·0
9	Iowa 103		,,	0	0	66·1	44·6	100·0
10	,, 105		,,	0	0	...	0	...
11	Iowar 670		,,	0	1·0	0	...	...
12	Gopher		,,	0	0	0	0	0
13	Kanota		,,	0	0	0	0·5	...
1	IP 1		*Sterilis*	19·0	46·7	84·2	49·4	100·0
2	IP 2		,,	4·0	54·9	92·0	73·4	98·0
3	IP 4		,,	13·4	52·0	73·5	66·8	100·0
38	Cross I*	140-53	*Sterilis*	14·9	53·1	68·0	36·7	91·0
39		361-33	,,	10·9	18·5	66·6	...	92·0
41		172-65	,,	10·2	20·7	67·1	78·2	100·0
42		271-68	,,	2·0	54·6	72·7	64·7	91·0
44		106-50	,,	9·5	22·3	65·7	50·9	98·0
45		79-46	,,	5·0	55·0	83·3	23·0	...
46		139-87	,,	20·3	43·3	65·2	54·7	100·0
48		80-40	,,	19·6	18·0	73·6	33·3	100·0
51		14A-35	,,	6·1	39·2	60·5	76·8	100·0
53		179-81	,,	18·2	32·3	92·5	..	...
58		270-49	,,	33·9	29·3	50·6	68·4	94·0
40		36-92	*Sativa*	34·7	17·7	68·5	84·6	...
47		207-95	,,	12·2	38·4	0	0	0·7
49		104-24	,,	7·9	21·7	54·0	62·5	99·0
50		336-38	,,	19·4	35·6	53·1	78·5	100·0
52		84-29	,,	4·9	23·8	41·3	78·3	100·0
54		323-51	,,	16·1	25·4	60·0	80·1	100·0

*Cross I = Scotch Potato oats × IP 4

TABLE I—*contd.*

Identity No.	Variety		Type of base	Percentage reaction to smut				
				Seeds infected without hulling	Seeds infected after hulling			
				1932-33	1932-33	1935-36	1936-37	1938-39
55		321-73 .	*Sativa* .	3·1	33·8	86·0	...	100·0
56		310-58 .	,, .	6·2	25·0	73·3	86·7	100·0
57		251-32 .	,, .	27·7	22·5	68·0	47·0	100·0
21	Cross II**	109-87 .	*Sterilis* .	24·8	31·8	48·2	49·7	...
22		19-70 .	,, .	41·2	47·1	61·1	71·5	98·0
25		52-87 .	,, .	28·2	32·1	64·5	33·5	94·0
26		93-70 .	,, .	16·7	62·4	61·5	80·9	100·0
27		248-5 .	,, .	37·9	29·0	72·7	52·1	...
31		327-58 .	,, .	28·8	50·0	83·9	54·6	...
32		186-80 .	,, .	38·8	62·0	78·5	...	...
34		162-53 .	,, .	11·6	15·0	75·0	26·1	...
35		8-64 .	,, .	9·3	19·1	62·8	41·6	100·0
18		112-89 .	*Sativa* .	37·7	28·9	38·8	37·0	94·3
17		284-79 .	,, .	40·4	56·6	45·9	46·2	100·0
19		281-83 .	,, .	31·8	54·7	76·5	59·9	98·0
20		151-9 .	,, .	20·2	40·5	70·6	20·5	99·0
23		262-88 .	,, .	8·1	40·8	64·6	43·5	100·0
24		97-84 .	,, .	5·2	42·8	40·0	12·4	97·0
28	Cross II	89-76 .	*Sativa* .	12·4	17·9	63·4	57·1	89·0
29		197-89 .	,, .	21·1	38·4	58·5	60·7	100·0
30		238-27 .	,, .	36·0	37·2	61·0	81·6	100·0
33		93-2 .	,, .	24·0	40·0	80·6	85·7	...
36		308-88 .	,, .	6·6	31·6	63·5	54·5	100·0
37		97-80 .	,, .	38·5	35·4	60·0	18·3	...
16	Cross III†	242-56 .	,, .	29·3	42·3	48·7	49·6	96·3
15	,, IV(*a*)‡	48-20 .	,, .	10·1	16·8	42·8	43·4	88·0
14		48-74 .	,, .	6·2	53·4	42·0	7·0	76·7
59	,, VII††	194 .	,, .	...	...	46·2	0	...
60		408 .	,, .	...	...	0	0·7	0

**Cross II =Scotch Potato oats × IP 2

†Cross III =Abundance × IP 4

‡Cross IV(*a*) =Iowa 103 × IP 1

††Cross VII =IP 4 × Kinwada S 10

showing that there is no linkage between smut-resistance and the *sativa* or *sterilis* type of base.

It will be noted that in 1938-39, the amount of smut in the susceptible varieties and even in those that had shown in previous years an increased resistance to smut was rather high. Two causes can be assigned to this : (1) a new physiologic race of the smut was used and, (2) the environmental factors at New Delhi were more favourable to smut attack. Results obtained by Coffman *et al.* [1931] demonstrate that differences in the reaction of host varieties to the different physiologic races might give different results in the same oat cross from inoculum of different forms and that seasonal and place variations in covered smut may modify apparent segregation. While environmental factors may, therefore, have influenced infection, the possibility of a mixture of physiologic races cannot entirely be ruled out, for though every precaution was taken against this, it is possible that a mixing up may have happened because of the difficulty in obtaining viable spores.

The immune and the highly resistant varieties are now being multiplied in the Botanical Section, and they will be distributed in areas where covered smut occurs in epiphytotic proportions, if they are otherwise found suitable.

Investigations on loose smut

Less attention has been given to this smut, as it occurs rather rarely. In 1928-29, however, an investigation was carried out to see how the varieties developed at Pusa compared with the one cultivated at Lyallpur in their reaction to a collection of loose smut collected at the latter place. It must be stated that no difficulty was experienced in keeping the spores of this smut viable. This investigation was carried out at Pusa and the results obtained are recorded in Table II.

Table II

Reaction of Pusa and Lyallpur varieties of oats to loose smut in 1928-29

Treatment of seed	Percentage of smutted plants			
	BS 1 (IP 1)	BS 2 (IP 2)	Pusa Farm seed	Lyallpur seed
Uninfected seed sown dry .	0	0·7	0	7·6
Seed soaked in water for two hours	0·1	11·6	0·4	40·8
Seed soaked in a heavy suspension of spores in water for 2 hours	0·1	14·5	0·5	45·0

It will be observed from the data recorded in this table that Imperial Pusa 1 and Pusa Farm seed were highly resistant to the Lyallpur race of loose smut and that Imperial Pusa 2 is moderately resistant. The Lyallpur variety is, however, very susceptible to the disease.

During the next year, the methods of infection were slightly modified. The results are recorded in Table III.

TABLE III

Per cent smut in IP 1 and Lyallpur oats at Pusa in 1929-30

Method of infection	Per cent smut	
	IP 1	Lyallpur oats
Ordinary seed	0·05	1·3
Ordinary seed soaked in water for 2 hours . . .	0·65	22·5
Seed infected before storing and sown dry . . .	19·41	34·4
Seed infected before storing and sown after soaking in water for 2 hours	66·9	78·1
Seed infected with dry spores before sowing . . .	18·2	25·7
Seed infected before sowing in a suspension of spores in water for 2 hours	51·1	91·3

The data show that the method of pre-treating the seed with viable spores has considerable influence in the occurrence of smut in the resulting crop. For successful infection of seed which has not been hulled, it would appear that infecting it with spores before they are stored away and soaking them in water for about 2 hours before sowing, ensures successful results. But removing the hulls of the seeds, smearing them with the spores and then germinating the seed in moist sand at a favourable temperature is by far the most satisfactory method.

DISCUSSION

Several years' work with the covered smut of oats both at Pusa and at New Delhi has shown that among them are varieties which are homozygous for resistance and susceptibility to this disease. Successful infection both by *U. Kolleri* and *U. Avenae* can be brought about by simple methods ; but the spores of *U. Kolleri*, which are known to keep viable for several years in countries with a temperate climate, lose their vitality under Pusa and Delhi conditions rather rapidly, rendering the task of breeding resistant varieties very difficult.

Physiologic specialization in the oat smuts has been demonstrated by Reed [1924, 1940] who has also given a list of differentials that should be used in their determination. These differential varieties do not, however, grow well under Indian conditions. A descendant of the original collection of the covered smut used in these investigations was therefore sent to Reed in 1935 and he [1940] now reports that that is a new race, to which he has assigned the number 14. It is possible that more than one such race exist in India.

Though cheap and efficient methods of treating oat seed to control both the covered and the loose smuts are available, the task of developing resistant

or immune varieties is of great importance in this country. Many of the better yielding and good quality oats in this collection having proved susceptible, it is proposed to test the resistance of other new Imperial Pusa hybrid varieties as time and opportunities permit.

Summary

Both the covered (*Ustilago Kolleri*) and the loose (*Ustilago Avenae*) smut of oats occur in India, but the former is by far the more widely spread disease. Efficient seed treatments to control them are available, but a varying degree of susceptibility to covered smut shown by the oat varieties under trial at Pusa led to these investigations being undertaken to see how far this resistance was due to inherent factors.

While no difficulty was experienced in obtaining viable spores of loose smut at the time of infecting the seed during sowing, it was noted that the spores of covered smut quickly lost their germinating power. If the smutted ears were wrapped, however, in blotting paper and stored in a refrigerator, the spores retained their viability.

Tests with 60 Indian and foreign varieties showed that some of the foreign varieties were immune to covered smut, but others were very highly resistant. None of the Indian varieties were resistant, but among the hybrids between the Indian and the exotic varieties, one proved to be immune to covered smut and another very highly resistant.

Physiologic specialization in Indian oat smuts presumably exists. The race of covered smut used in these studies was determined by Reed to be a new one to which he has assigned the number 14.

Acknowledgements

Finally we wish to thank Dr B. P. Pal and Dr G. Watts Padwick for critically reading through the manuscript of this paper and for suggestions. We also wish to express our gratitude to Dr G. M. Reed for determining the physiologic race to which our smut belonged.

References

Coffman, F. A., Stanton, T. R., Bayles, B. B., Wiebe, G. A., Smith, R. W. and Tapke V. F. (1931). *J. agric. Res.* **43**, 1085-99

Diehl, O. (1925). *Bot. Arch.* **9**, 146-99

Fischer, G. W. (1936). *Phytopathology* **26**, 1118-27

Mundkur, B. B. and Khan, A. (1934). *Indian J. agric. Sci.* **4**, 899-905

Reed, G. M. (1924). *Amer. J. Bot.* **11**, 483-92

——————(1940). *Amer. J. Bot.* **27**, 135-43

Reed, G. M. and Faris, J. A. (1924). *Amer. J. Bot.* **11**, 579-99

Sampson, K. (1928). *Ann. appl. Biol.* **15**, 586-612

Sobel, M. (1933). *Biologist* **15**, 95-6 (Original not seen)

VARIATION IN THE MEASURABLE CHARACTERS OF COTTON FIBRES

II. VARIATION AMONG SEEDS WITHIN A LOCK*

BY

R. L. N. IYENGAR, M.Sc.

Agricultural Research Institute, Coimbatore

(Received for publication on 5 December 1939)

(With Plate XXXVII and two text-figures)

THE large amount of variation that is incident in any sample of cotton has been analysed in detail by Turner [1929], who has enumerated the various factors that are responsible for producing the variation. The purpose of the present studies is to enquire into the extent of variation that would be caused by some of the factors enumerated by Turner. The variation of fibre weight with respect to the length of the fibre was studied by Turner and Iyengar [1930] and the variation of other properties with length has been dealt with in another place [Iyengar, 1939]. The present work contains the study of the variation with respect to the position of the seed in the lock, that is, a variation in relation to the proximity or otherwise to the source of food supply within a boll.

Turner [1929] himself has recorded a number of determinations on this point in locks of A 19 and has observed some wide differences. Unfortunately the positions of the seeds in the lock were not made clear. Ramanatha Ayyar and Jagannatha Rao [1930] determined the halo length of seeds in different positions and found distinct variations among them. Sen [1932] working on Punjab cottons observed that the fibre weight per unit length for the apical seed is lowest, whereas fibres from the seeds nearest the base have comparatively higher weights per unit length than the fibres from any other seed in the lock. Armstrong and Bennett [1933] found an increase in mean fibre length from the base of the lock up to the sixth position. It is thus seen that different workers have found definite differences in some of the characters they studied.

The present investigation is divided into two parts; the first deals with certain seed and lint characters, the second part being devoted to description of the fibre characters and the inter-relationships.

§ I. Seed and lint characters

Material and sampling

For the complete study of the seed, lint as well as the fibre characters, made in this enquiry, the material consisted of three pure strains, viz. Co 1 (*G. hirustum*), Co 2 (*G. hirsutum*) and Karunganni 546 (*G. indicum*).** For

* Part of the thesis submitted for the M.Sc. degree of the Madras University

** These samples are Nos. 1, 2 and 10 of Tables VI—X.

a further detailed study of the seed and lint characters alone, a number of other pure strains were utilized. The sampling was made with the object of eliminating, or reducing to a minimum, almost all the extraneous influences other than the one under enquiry. This was done by confining the picking to that of a single day and that too to as few plants as were necessary and picking only bolls of similar locular composition, either three-locked or four-locked according to the variety of cotton. Even amongst these only such locks that contained no aborted or undeveloped seeds were selected.

The seeds in the lock were numbered in the following manner, suggested by Rao Bahadur Ramanatha Ayyar. If a lock of cotton is held such that the funicular ends of the seeds face the observer and the tapering end* of the lock points bottomwards (Fig. 1) it will be seen that the seeds are arranged alternately on opposite sides of the medial line. The seeds located on either side belong to two different placenta. If the seed nearest to the pedicel is reckoned as the first, and if this happens to lie on the left side of the medial line, then all the seeds on the left side will bear consecutive odd numbers as we travel downwards, while those on the right side the consecutive even ranks. If the first seed were on the right side, all odd-numbered seeds will occupy that side and even-numbered the other side. It was observed that the occurrence of the first seed either on the right or on the left side of the lock does not follow any definite rule.

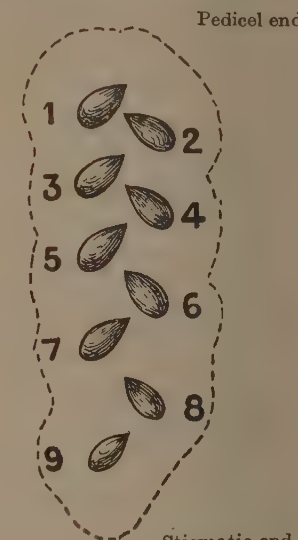


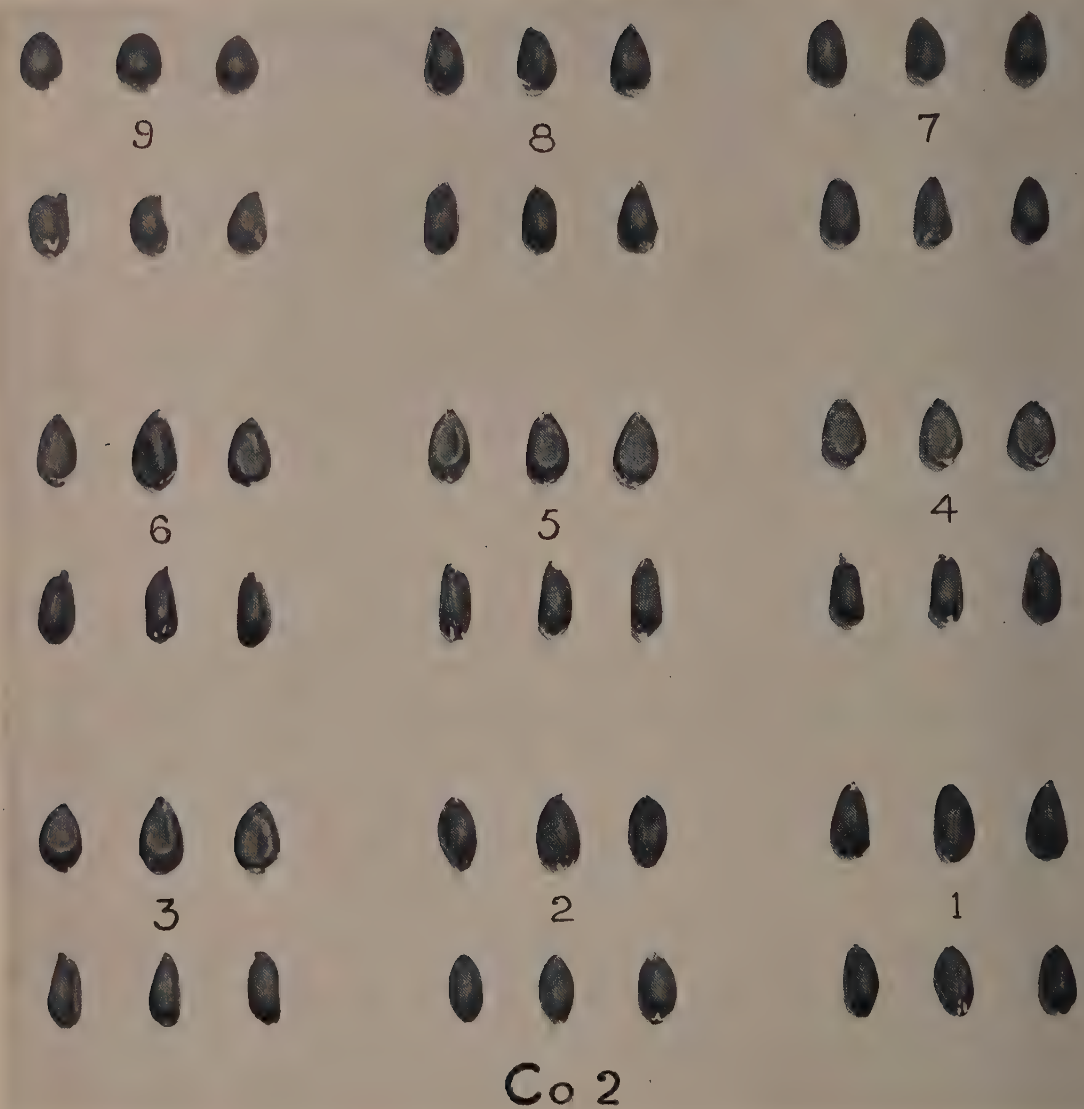
Fig. 1

It may be mentioned here that Sen [1932], who has worked on a similar problem, has taken the seed at the stigmatic end as first and it, therefore, corresponds to the last seed according to the present method of numbering. He has, however, presumed this seed to lie always in the centre and counted the next seed to the left as second. This method of numbering is defective since the first seed should either be on the right or left placentum. In the former case the second seed will be on the left side, while in the latter case it will be on the right side on account of the alternate disposition. The method of taking the seed on the left always as second thus introduces the error of mixing seeds of consecutive positions and masks the inherent difference, if any, between the positions.

Experimental procedure

The seeds of the corresponding positions of each lock were sorted out and clubbed together. They were carefully delinted by hand so as not to break any of the fibres. The lint and seeds were weighed after drying them in

* The tapering end of the lock corresponds to the stigmatic end of the boll.



The numbers represent the position of the seed in a lock, 1 corresponding to the pedicel end and 9 to the stigmatic end. Six seeds are shown for each position, the upper three and the lower three indicating the appearance of the seeds in two directions at right angles to each other.

desiccators till the weight became approximately constant. They were used for the study of the following charactors.

1. Seed weight
2. Lint weight
3. Ginning percentage
4. Embryo weight
5. Seed-coat weight
6. Fibre length
7. Fibre weight
8. Immaturity of fibres
9. Number of fibres per seed
10. Surface area of the seed

In addition, a further set of 22 samples from pure strains was studied for the verification of the variation in the first five characters. In 12 of them, the total number of seeds in each position was divided into sub-samples of 10 seeds each. Each sub-sample was delinted separately and its seed weight and lint weight were determined. After cutting the seeds open, the embryo weight as well as the seed-coat weight of each sub-sample was also determined. From these individual weights the standard errors were calculated.

The fibre length was determined by making two Balls' Sorter tests on two independent slivers. The fibre weight was obtained by using the cutting method* and determining the weights for the different group-lengths of fibres, following, in all detail, the procedure described in the previous work [Iyengar and Turner, 1930]. For each position five group-lengths were tested and eight weighings of about 250 fibres each were made for each group-length. This method enabled the calculation of the number of fibres per seed**. The maturity of the fibres was estimated by employing Clegg's [1932] method. As in the case of the fibre weight this attribute also was determined for each group-length. But unfortunately, as this investigation was taken up last, sufficient quantity of sliver was not available for all the positions of Co 2 and K 546. Ten tufts containing about 100 fibres in each were examined for Co 1, six tufts for Co 2 and seven for K 546.

In order to estimate the number of fibres per unit area of the seed surface, the surface area of the seeds had to be calculated. Turner [1929] estimated the area as being proportional to $\sqrt[3]{(\text{Seed—volume})^2}$, by assuming that the seeds were, on the average, uniform in shape. Armstrong and Bennett [1933] considered that ' the cotton seed is practically a prolate spheroid ' and calculated the surface area from the external dimensions of the seed using a formula derived under the above assumption. But it will be seen in Plate XXXVII that the seeds dealt with in the present study are not similar in shape. The seeds nearest the stigmatic end are seen to approach the spherical form but for a slight projection near the funicle ; those near the pedicel are three-sided, two sides being concave and the third convex. The seeds in the middle of the lock, though varying among themselves, exhibit the general appearance of a prolate spheroid pressed at the two sides, both the presssed sides being concave.

* This method was followed since it was in vogue in 1930 and 1931 when this work was carried out.

** As already stated, the lint weight was determined after desiccation, while the fibre weight is that which is corrected to 70 per cent relative humidity. The desiccated samples of lint were kept in a chamber containing a solution of calcium chloride giving a relative humidity of 70 per cent, the increase in weight was determined and the required correction was applied in calculating the number of fibres per seed.

Since concave surfaces, while increasing the area, reduce the volume, the calrelation of the surface area from the external dimensions will not give accurate results in the present case.

The method developed by the writer for the measurement of surface area [Iyengar, 1929] was employed. According to that method the fuzz on the seeds was completely removed by treating the seeds uniformly with concentrated sulphuric acid. The seeds of each position were divided after washing and drying into sub-samples, six lots of 20 seeds for each position in Co 1, four of 20 for Co 2, and four of 32 seeds for K 546. Each of these lots was immersed in liquid paraffin for a definite period and then removed into the tubes of a centrifuge and rotated with a constant head of water for a definite time. With a view to counterbalance the variations, if any, in the speed of rotation of the centrifuge, samples of seeds from different positions were used for the four receptacles. The head of water was kept practically constant throughout the work. As wire-gauze bottoms were provided for the tubes, the excess of liquid drained away and only a thin layer was left on the surface. The increase in the weight of the seeds was taken as a measure of the surface area*.

The seeds of each position were then cut open and the embryos removed carefully from the enclosing coats and their weights were determined.

In addition to these, in strain Co 1 the density of the seeds was determined according to the method described by Turner [1929, 1] by the displacement of liquid paraffin in a specific gravity bottle.

Discussion of results

Abraham and Ramanatha Ayyar [1937] have observed that the primor dial ovules are produced alternately on either placenta as we travel from the pedicel towards the stigma and that the ovule nearest the pedicel always aborts, the second one being the first to get fertile. The first seed of the present study is thus the second of the primordial ovules and it is the first seed in one placentum. The second seed is the first fertile seed on the other placentum though it corresponds to the second primordial ovule in that placentum. We may now consider which of the seeds in the two placenta may be taken as being in the same level, whether they are 1 and 2, 3 and 4, etc., or 2 and 3, 4 and 5, etc. The differences** 1—2, 3—4, etc., which we shall for convenience call A, and the differences 2—3, 4—5, etc., which we shall call B, have been calculated. The mean values of A and B for the different species are given in Table I. It will be seen that A is less than B in all cases except for seed weight and embryo weight in *hirsutum* and *cernuum*. But the difference between A and B is not very large nor can its significance be assessed statistically. We may therefore state that, roughly, seeds 1 and 2, 3 and 4, etc. may be more nearly on the same level than 2 and 3, 4 and 5, etc.

* The centrifuge used for Co 1 was different from that used for Co 2 and K 546. The value of the constant for the last two was, therefore, different from that for the first.

**The arithmetical value of the difference without reference to sign has been considered here, as we are concerned only with the magnitude of the difference and not the direction.

Table I

Differences in weights in mg. (between placenta)

Property	Difference	*Hirsutum*		*Herbaceum*		*Arboreum*		*Cernuum*		All cottons	
		A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Seed weight	1—2	3·44		1·92		1·12		2·57		1·88	
	2—3		1·24		1·15		0·88		1·47		1·06
	3—4	1·16		0·06		0·45		1·87		0·79	
	4—5		1·30		2·62		1·85		1·03		1·83
	5—6	2·32		3·60		1·40		0·63		1·86	
	6—7		3·16		5·50		2·84		2·40		3·14
	Mean	2·31	1·90	1·86	3·09	0·99	1·86	1·69	1·63	1·51	2·01
Embryo weight	1—2	2·86		1·15		0·88		2·43		1·11	
	2—3		0·96		0·70		0·61		0·93		0·72
	3—4	1·16		0·28		0·46		0·90		0·61	
	4—5		0·78		1·48		1·01		0·53		0·98
	5—6	1·24		1·32		0·98		0·43		1·02	
	6—7		1·66		2·40		1·48		0·57		1·48
	Mean	1·75	1·13	0·92	1·53	0·77	1·03	1·25	0·68	0·91	1·06
Seed-coat weight	1—2	1·00		0·62		0·42		1·63		0·71	
	2—3		0·62		0·35		0·71		0·33		0·54
	3—4	0·92		0·42		0·25		0·63		0·46	
	4—5		0·94		1·00		0·71		1·53		0·90
	5—6	0·72		1·12		0·58		0·60		0·70	
	6—7		1·80		2·10		0·78		1·70		1·42
	Mean	0·88	1·12	0·72	1·15	0·42	0·73	0·95	1·18	0·62	0·95
Lint weight	1—2	3·06		1·30		0·65		4·03		1·64	
	2—3		4·52		0·80		1·72		2·80		2·27
	3—4	0·64		0·58		0·85		0·63		0·74	
	4—5		1·56		1·02		1·71		4·27		1·88
	5—6	1·86		1·05		0·77		0·17		0·92	
	6—7		1·98		2·00		1·43		2·10		1·74
	Mean	1·85	2·69	0·98	1·27	0·76	1·62	1·68	3·06	1·10	1·96

TABLE II

Differences in weights in mg. (within a placentum)

Property	Difference	*Hirsutum* C	*Hirsutum* D	*Herbaceum* C	*Herbaceum* D	*Arboreum* C	*Arboreum* D	*Cernuum* C	*Cernuum* D	All cottons C	All cottons D
Seed weight	1—3	4·56		3·08		1·35		4·03		2·59	
	2—4		2·00		1·20		0·82		2·67		1·32
	3—5	2·36		3·02		2·15		1·37		2·24	
	4—6		2·30		5·98		3·05		0·73		3·11
	5—7	2·94		8·40		3·72		2·17		3·73	
	Mean	3·29	2·15	4·87	3·59	2·41	1·94	2·52	1·70	2·85	2·22
Embryo weight	1—3	3·78		1·85		1·12		3·37		2·04	
	2—4		2·08		0·80		0·77		1·83		1·16
	3—5	1·14		1·38		0·93		1·17		1·07	
	4—6		1·74		2·80		1·75		0·77		1·87
	5—7	1·06		3·50		1·51		0·60		1·77	
	Mean	1·99	1·41	2·24	1·80	1·19	1·26	1·71	1·30	1·63	1·52
Seed-coat Weight	1—3	1·14		0·88		0·50		1·37		0·79	
	2—4		1·12		0·32		0·75		0·63		0·74
	3—5	1·86		1·42		0·93		0·97		1·20	
	4—6		1·18		2·12		1·23		1·00		1·34
	5—7	1·98		3·30		1·26		1·17		1·63	
	Mean	1·66	1·15	1·87	1·22	0·90	0·99	1·17	0·82	1·21	1·04
Lint weight	1—3	1·61		1·90		1·54		1·23		1·60	
	2—4		4·40		0·82		2·63		2·17		2·64
	3—5	1·44		1·60		2·51		3·63		2·26	
	4—6		3·42		2·02		2·31		4·30		2·73
	5—7	3·84		2·64		1·88		2·00		2·50	
	Mean	2·30	3·91	2·05	1·42	1·98	2·47	2·29	3·24	2·12	2·68

We may now consider the variation within the same placentum. The mean differences 1—3, 3—5, etc. which we shall call C and mean differences 2—4, 4—6, which we shall call D, are recorded in Table II. It will be seen that C is greater than D in all cases for seed weight. So also is it for embryo weight and seed-coat weight except in *arboreum*. On the other hand, for lint weight, C is less than D in all cases except in *herbaceum*. It may, therefore, be concluded that, but for a few exceptions, in the placentum in which the first fertile seed appears the difference between successive seeds is greater for seed weight, embryo weight and seed-coat weight and in the other placentum the variation in lint weight is greater.

We may now consider in detail the variation of the characters.

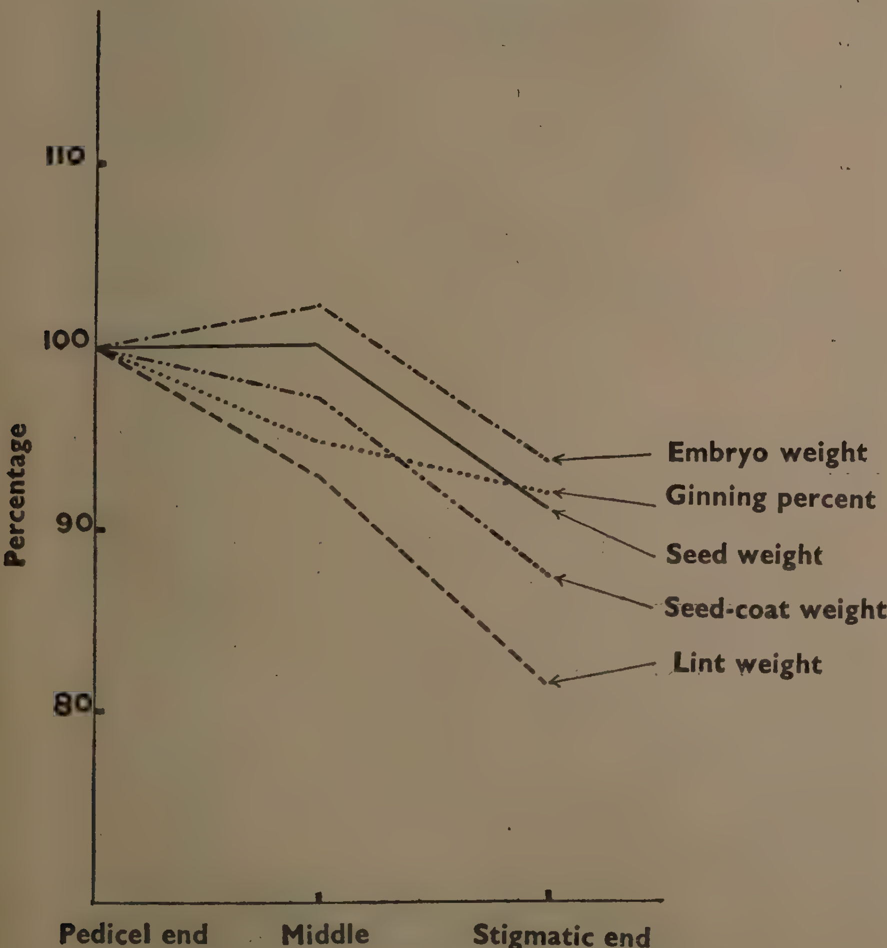


FIG. 2. Variation of characters in different regions

TABLE

Values for the regions expressed as percentage

Property	Pedicel region	Middle region									
		Hirsutum		*Herbaceum*		*Arboreum*		*Cernuum*		All cottons	
		Value	S. E.	Value	S. E.	Value	S. E.	Value	S. E.	Value	S. E.
Seed weight . .	100	101·24	0·90	102·50	1·11	99·52	0·59	98·07	1·55	100·16	0·48
Embryo weight .	100	104·36	0·57	103·88	0·97	101·19	0·87	101·37	2·06	102·28	0·58
Seed-coat weight .	100	97·86	0·95	100·15	0·86	97·50	0·72	94·10	0·37	97·59	0·52
Lint weight . .	100	95·18	1·09	103·70	2·74	89·40	1·50	90·67	0·85	93·00	1·33
Ginning percentage	100	96·04	0·34	100·75	1·51	92·41	1·12	96·13	0·26	94·92	0·86

Seed weight	Pedicel ∼ middle	N
	Pedicel ∼ stigmatic	N
	Middle ∼ stigmatic	N
Embryo weight	Pedicel ∼ middle	HS
	Pedicel ∼ stigmatic	N
	Middle ∼ stigmatic	N
Seed-coat weight	Pedicel ∼ middle	N
	Pedicel ∼ stigmatic	S
	Middle ∼ stigmatic	N
Lint weight	Pedicel ∼ middle	HS
	Pedicel ∼ stigmatic	HS
	Middle ∼ stigmatic	S†
Ginning percentage . . .	Pedicel ∼ middle	HS
	Pedicel ∼ stigmatic	HS
	Middle ∼ stigmatic	S

* Data of mean values for middle and 'stigmatic' regions expressed as percentage

N = Not significant; S = significant for

** Difference very near the value

† Difference very near the value

III

of the value for the pedicel region

Stigmatic region										By analysis of variance* (all cottons)		
Hirsutum		*Herbaceum*		*Arboreum*		*Cernuum*		All cottons		Mean square between regions	Critical difference†	
Value	S. E.	Value	S. E.	Value	S. E.	Value	S. E.	Value	S. E.		P=0 5	$P=0{\cdot}1$
97·12	1·50	92·80	1·06	91·67	1·36	80·60	0·83	91·61	1·18	742·08 HS	2·01	2·73
102·32	0·90	94·78	1·30	92·05	2·03	84·60	0·37	93·64	1·46	931·39 HS	2·43	3·30
92·48	1·71	92·78	1·78	90·81	1·34	78·00	1·08	89·85	1·19	748·07 HS	1·82	2·47
87·16	1·64	93·88	3·89	77·86	2·02	71·23	0·89	81·49	1·85	1655·43 HS	1·67	2·28
93·66	0·55	101·12	3·14	88·62	1·98	94·00	0·00	92·27	1·41	87·39 HS	1·36	1·84

N	N	N	N	N
HS	HS	HS	HS	HS
HS	HS	HS	HS	HS
S	NS	N	HS	N**
S	HS	HS	HS	HS
HS	HS	S	HS	HS
N	HS	HS	HS	S†
S	HS	HS	HS	HS
S	HS	HS	HS	HS
N	HS	HS	HS	HS
N	HS	HS	HS	HS
N	HS	HS	HS	HS
N	HS	HS	HS	H
N	HS	HS	HS	HS
N	N	HS	N	HS

of pedicel value—last two columns of Tables VI — X
$P = 0{\cdot}05$; HS = significant for $P = 0{\cdot}01$;
for significance for $P = 0{\cdot}05$
for significance for $P = 0{\cdot}01$

(*1*) *Seed weight*

The results are given in Table VI. It will be seen that for five samples, viz. K 546(Koilpatti), Verum early, *G. sanguineum* (black soil), Mollisoni and N 14 (black soil), the highest value appears in the second position. For practically all the remaining samples the maximum is reached in a position between the second and the middle of the lock, there being a rise up to that position accompanied by a gradual decline later on. It may be noticed that the rise is rather slow and the fall is more rapid, especially when the number of seeds constituting the lock is large as in *G. cernuum*.

The seeds in the lock may be roughly divided into three regions : (1) pedicel, (2) middle and (3) stigmatic, for it would then be possible to club together cottons with varying locular compositions. The figures are given at the end of Table VI. Taking the value for the pedicel end as 100, the values for the other two regions have been expressed as a percentage of it. The mean values of these percentages when the cottons within a species are clubbed together and when all the cottons are clubbed together are recorded in Table III. The significance of the various differences, according to both standard error and analysis of variance, is also indicated in the same table. It will be seen that for the property under consideration here, namely the seed weight, the three differences in *hirsutum* and the difference between the pedicel and middle regions in the other cases are not significant. The remaining differences are highly significant. This means that the factors responsible for the production of seed weight are equally efficient in the pedicel as well as the middle regions, but far less so in the stigmatic region (excepting in *hirsutum*).

(*2*) *Embryo weight*

The values for this character are reproduced in Table VII. For N 14 (black soil) the highest value is in the first and second positions. Three samples, namely K 546 (Koilpatti), *G. sanguineum* (black soil) and Mollisoni, record the highest value in the second position and all the rest of the samples in approximately the middle of the lock. The rise and fall appears to be similar to that observed in the case of the seed weight though not of such a magnitude.

The percentage values for the three regions denote that all the differences excepting four are significant. (It will be seen that the difference between the pedicel and middle regions is significant according to the standard error, while according to the analysis of variance it is not. The difference is, however, near the value required for significance in the latter case). This means that, excepting in *arboreum* and *cernuum*, the embryo weight is highest in the middle region, less in the pedicel region and still less in the stigmatic region (excepting in *hirsutum*). The activity for the production of the embryo weight thus appears to be maximum in the middle of the lock (Fig. 2).

(*3*) *Seed-coat weight*

The figures are found in Table VIII. It will be seen that about half the number of cottons have the maximum value in the second position and the remaining in a position intermediate between the second and the centre of the lock. There is a gentle rise up to the maximum with a fall later.

The percentages in the different regions denote that all the differences except three are significant. The pedicel region records the highest value, the middle a lower one and the stigmatic region a much lower value. The activity that produces this character may, therefore, be said to deteriorate gradually with the distance from the pedicel.

(4) *Lint weight*

These results are given in Table IX. For three cottons, namely K 546 (Coimbatore, five seeded) and both samples of N 14, the highest weight is in the first position. For four others, namely Nadam, 2405 (black soil) and both samples of 2919, it is approximately in the middle of the lock. For almost all the remaining samples the maximum value is found in the second position, there being a rise from the first to the second position followed by a gradual decrease towards the end of the lock. The fall in lint weight is much greater than in the other characters for most of the cottons.

When the percentage values for the regions are considered, it will be seen that, excepting the three differences for *herbaceum*, all are highly significant. The activity for the production of lint is thus greatest near the pedicel, less in the middle and least near the end of the lock, gradually decreasing with the distance from the source of food supply (excepting in *herbaceum*).

(5) *Ginning percentage*

Table X contains the results. Four samples, namely Nadam, Mollison and both samples of 2919 denote little fluctuation among the positions. 2405 (black soil) records a gradual increase with advance of position. Three samples of K 546 (Coimbatore) and two of N 14 exhibit the maximum value in the first position. Most of the remaining samples record the highest value in the second position, there being a continuous fall towards the end of the lock.

The values for the regions exhibit a behaviour almost similar to that shown by the lint weight, the percentage decreasing significantly with the distance from the pedicel excepting in the *herbaceum* cotton.

Summing up the foregoing conclusions, it may be stated that the lint is produced in the largest quantity nearest the source of food supply and decreases rapidly with the distance from the source. The embryo, on the other hand, is produced in the largest quantity rather farther from the source of food supply, that is near the middle of the lock. The seed-coat which comes in between the embryo and lint exhibits an intermediate trend of variation. The seed which is composite of the embryo and seed-coat follows a middle course (Fig. 2). In *G. cernuum* the number of seeds in a lock is considerably more than that in other cottons, being nearly double. Hence the nutrition will have to travel a longer length to reach the distal end (stigmatic region) of the lock. The reduction in the seed weight, lint weight, embryo weight and seed-coat weight at the stigmatic end for this cotton is found to vary from 15 to 30 per cent, which is considerably more than what is observed in cottons with fewer seeds in the lock.

The foregoing conclusions, namely the largest deposition of cellulose (lint) being nearest the source of food supply, while that of proteins, fats, minerals, etc. (embryo) being farther from it appears to be rather a paradox. Some cytological or physiological investigation may throw light on this.

Incidentally, we may record the effects, observed in the present investigation, of variation in the number of seeds in the lock and of the kind of soil in which the plants were grown. The figures are found in Tables VI—X. It will be seen generally that the mean values of the seed weight and embryo weight exhibit an increase with the decrease in the number of seeds constituting a lock, though this is not always strictly true. The ginning percentage and seed-coat weight remain practically unaffected. Coming to the soil variation, it will be seen that the red soil* has produced greater seed weight, embryo weight and seed-coat weight in all the three strains studied, viz. N 14, 2405 and *G. sanguineum*. More lint weight is also produced by the same soil except in N 14. This strain records a reduction in the red soil for ginning percentage. In the other two strains the difference is not large.

(6) *Surface area of seed*

The results are given in Table IV.

TABLE IV

Surface area of seeds in arbitrary units

Position of seeds	Co 1 ($\times k$)	Co 2 ($\times k^1$)	K 546 ($\times k^1$)
Pedicel end —			
I	1.71	1.72	0.80
II	1.82	1.85	0.84
III	1.83	1.82	0.83
IV	1.76	1.87	0.80
V	1.80	1.86	0.80
VI	1.81	1.86	0.80
VII	1.81	1.81	0.81
VIII	1.80	1.83	..
IX	1.83	1.76	..
Stigmatic end—			

Except for a rise from the first to the second position there does not appear to be much fluctuation in the surface area.

(7) *Density of seed*

The results which were obtained from Co 1 only are given in Table V.

*Irrigation was given in the red soil but not in black soil.

TABLE V

Density of seeds

Position of seed	Density in gm. per c.c.
Pedicel end—	
I	1.006
II	1.003
III	1.020
IV	1.013
V	1.011
VI	0.999
VII	0.978
VIII	0.978
IX	0.976
Stigmatic end—	

The density appears roughly to rise up to about the middle of the lock with a fall later.

CONCLUSION

(1) The lint is found to be produced in the largest quantity alomst nearest the source of food supply and decreases rapidly towards the end of the lock except in *herbaceum*.

(2) The embryo has the highest weight rather farther from the source of food supply than was found in the case of the lint. The decrease towards the end of the lock is also less marked.

(3) The seed-coat, which comes in between the embryo and the lint, exhibits an intermediate trend of variation.

(4) The seed, which is a composite of the embryo and seed-coat, follows a middle course.

(5) The foregoing conclusion, viz. the highest deposition of cellulose (lint) being nearest the source of food supply, while that of proteins, fats, minerals, etc. (embryo) being rather farther from it appears to be a paradox. Further cytological or physiological work may throw some light on this paradox.

(6) The ginning percentage is highest in the pedicel region and decreases with advance of position except in *G. herbaceum*.

(7) The seed weight, lint weight and embryo weight are generally (though not universally) found to increase with the reduction in the number of seeds constituting the lock.

(8) The red soil (which was irrigated) is found to produce an increase in seed weight, embryo weight and seed-coat weight in all the three strains studied and an increase in lint weight also in two of them, over the black soil (which was not irrigated). The same red soil has caused a reduction in the ginning percentage in one strain but not much difference in the other two.

(9) Except for a rise from the first to the second position there does not appear to be much variation in the surface area of the seeds.

(10) Roughly speaking the density of the seed may be said to rise up to the middle of the lock with a fall later.

TABLE

Seed

No.*	Name of cotton	No. of seeds in lock	Species	Soil	Pedicel end 1	2	3	4	5	Posi- 6
1	Co 1	9	*G. hirsutum*	Red	116·1	118·9	122·1	122·6	124·5	126·2
					119·0			124·4		
2	Co 2	9	Do.	„	136·8	139·7	140·0	141·0	138·2	141·7
					138·8			140·3		
3	Co 1	9	Do.	„	118·0	121·1	122·3	121·9	120·1	120·7
					120·5			120·9		
4	Do.	8	Do.	„	123·1	128·1	129·3	128·7	128·1	125·6
					126·8			128·4		
5	Do.	7	Do.	„	125·0	128·4	128·1	124·8	123·9	121·6
					126·7		125·6			121
6	2405	6	*G. herbaceum*	Black	52·5	54·3	55·9	54·9	50·4	47·2
					53·4		55·4		48·8	
7	2405	7	Do.	Red	60·9	62·3	62·3	61·3	60·6	56·8
					61·6		61·4			54
8	2919	6	Do.	Black	69·1	70·9	71·2	71·	68·6	64·2
					70·0		71·4		66·4	
9	2919	7	Do.	„	67·5	70·2	72·9	72·8	70·4	68·4
					68·8		72·0			64
10	K 546 (Koilpatti)	7	*G. indicum*	Black	53·9	55·4	54·2	53·9	52·7	52·3
					54·6		53·6			51
11	K 546 (Coimbatore)	8	Do.	„	50·7	52·3	53·0	52·6	50·7	51·9
					52·0			51·6		
12	Do.	7	Do.	„	50·6	52·1	52·1	52·0	51·5	50·2
					51·4		51·9			49
13	Do.	6	Do.	„	54·1	55·3	55·8	55·2	53·3	51·3
					54·7		55·5		52·3	
14	Do.	5	Do.	„	57·1	58·2	57·6	57·6	55·7	
					57·6		57·6	56·6		
15	N 14	6	Do.	„	40·7	41·3	40·5	39·6	36·3	34·5
					41·0		40·0		35·4	
16	Do.	6	Do.	Red	49·3	49·3	50·7	48·8	48·3	45·0
					49·3		49·8		46·6	
17	Verum early	9	*G. neglectum*	Red	51·4	51·8	50·9	50·8	48·7	48·7
					51·4			49·6		
18	Chandajari	7	Do.	„	49·5	50·8	51·9	51·9	49·7	49·1
					50·1		51·2			47
19	Mollisoni	8	Do.	„	59·8	59·6	58·0	58·7	56·7	55·9
					59·1			57·7		
20	Nadam	7	*G. obtusifoleum*	Red	49·8	51·6	52·4	52·5	50·5	48·5
					50·7		51·8			46
21	*G. sanguineum*	7	*G. sanguineum*	Black	38·5	40·8	39·4	38·8	35·8	34·2
					39·6		38·3			32
22	Do.	7	Do.	Red	44·8	45·8	46·2	46·4	44·8	43·0
					45·3		45·8			41
23	*G. cernuum*	16	*G. cernuum*	Red	73·0	77·4	80·0	79·0	79·9	80·4
					77·8					
24	Do.	15	Do.	„	80·6	82·9	83·4	84·3	85·1	84·5
					83·7					
25	Do.	14	Do.	„	77·3	78·3	79·6	83·3	81·9	82·7
					80·1					

* Nos. 1, 2 and 10 constituted

VI

weight

tion		Stigmatic end								Mean	Regional mean as percentage of pedicel value		
7	8	9	10	11	12	13	14	15	16		Pedicel	Middle	Stigmatic
123·0	120·9	120·5								121·6	100·0	104·5	102·2
	121·5												
138·0	134·0	135·5								138·3	100·0	101·1	97·8
	135·8												
116·3	110·6	110·9								118·0	100·0	100·2	93·0
	112·0												
121·6	120·2									125·6	100·0	101·3	96·6
122·5													
121·1										124·7	100·0	99·1	96·0
·4													
										52·5	100·0	103·8	91·5
52·9										59·6	100·0	99·6	90·5
·8													
										69·2	100·0	102·0	95·0
61·3										69·1	100·0	104·6	94·2
·8													
50·2										53·2	100·0	98·1	93·6
·2													
49·6	48·8									51·5	100·0	99·1	96·3
50·1													
47·										50·9	100·0	101·0	93·5
[illegible]													
										54·2	100·0	101·5	95·5
										57·2	100·0	100·0	98·1
										38·8	100·0	97·5	86·4
										48·6	100·0	101·0	93·5
47·3	43·7	41·2								48·3	100·0	96·5	85·7
	44·1												
45·2										49·7	100·0	102·1	94·0
·2													
53·2	49·4									56·4	100·0	97·5	89·3
52·8													
44·0										49·9	100·0	102·2	91·0
·2													
30·1										36·8	100·0	96·2	80·9
·2													
40·7										44·5	100·0	101·0	92·1
·8													
79·7	80·3	76·6	76·1	74·0	69·0	65·6	62·2	57·8	56·9	73·0	100·0	100·0	80·2
		77·8					62·3						
80·7	81·2	78·0	73·1	72·9	71·4	67·9	61·7	58·0		76·4	100·0	95·0	79·4
	79·5					66·4							
80·0	79·5	75·9	72·5	69·2	66·9	59·1	61·1			74·8	100·0	99·2	82·2
	79·5				65·8								

the samples for the main study.

TABLE

Embryo

No.*	Name of cotton	No. of seeds in lock	Botanical species	Soil	Pedicel end 1	2	3	4	5	Posi- 6
1	Co 1	9	*G. hirsutum*	Red	63·9	67·2	68·0	69·2	70·4	71·5
						66·4			70·4	
2	Co 2	9	Do.	"	75·6	78·5	79·5	80·5	80·8	83·0
						77·9			81·4	
3	Co 1	9	Do.	"	67·6	69·6	71·8	72·5	72·0	73·8
						69·5			72·8	
4	Do.	8	Do.	"	69·5	73·0	73·3	75·0	74·8	76·1
						71·9		74·9		
5	Do.	7	Do.	"	71·5	74·1	74·4	75·6	74·1	74·1
					72·8			74·7		73
6	2405	6	*G. herbaceum*	Black	25·6	26·4	27·8	27·6	25·0	23·2*
					26·0		27·7		24·1	
7	2405	7	Do.	Red	31·4	32·3	32·5	32·6	32·1	30·5
					31·8			32·4		29
8	2919	6	Do.	Black	34·1	35·7	35·9	36·2	34·6	33·3
					34·9		36·0		34·0	
9	2919	7	Do.	"	33·4	34·7	35·7	35·9	34·7	34·1
					34·0			35·4		32
10	K 546 Koilpatti	7	*G. indicum*	Black	30·7	32·9	32·3	32·5	31·7	30·8
					31·8			32·2		30
11	K 546 Coimbatore	8	Do.	"	25·5	26·6	27·4	28·2	27·4	27·0
						26·5		27·8		
12	Do.	7	Do.	"	26·6	28·4	28·2	28·5	28·1	27·1
					27·5			28·3		26
13	Do.	6	Do.	"	29·3	29·7	30·7	30·3	30·2	28·1
					29·5		30·5		30·1	
14	Do.	5	Do.	"	30·9	31·5	31·3	31·0	29·5	
					31·2		31·3	30·2		
15	N 14	6	Do.	"	21·6	21·6	21·2	20·6	18·4	17·0
					21·6		20·9		17·7	
16	Do.	6	Do.	Red	26·7	27·4	28·2	27·2	27·4	25·6
					27·0		27·7		26·5	
17	Verum early	9	*G. neglectum*	Red	27·9	28·0	27·4	28·3	27·5	27·6
						27·8			27·8	
18	Chandajari	7	Do.	"	27·1	28·2	28·6	29·1	27·9	27·4
					27·6			28·5		26
19	Mollisoni	8	Do.	"	34·2	35·0	33·9	33·8	32·7	32·4
						34·4		33·2		
20	Nadam	7	*G. obtusifolium*	Red	25·4	26·7	27·5	27·6	26·4	25·7
					26·0			27·2		24
21	*G. sanguineum*	7	*G. sanguineum*	Black	20·9	21·6	21·1	20·9	19·0	17·6
					21·2			20·3		16
22	Do.	7	Do.	Red	25·2	25·8	26·3	26·9	26·0	24·9
					25·5			26·4		24
23	*G. cernuum*	16	*G. cernuum*	Red	30·0	32·8	34·5	35·2	35·4	36·2
							33·4			
24	Do.	15	Do.	"	33·2	35·3	36·4	36·8	37·8	38·0
							35·9			
25	Do.	14	Do.	"	34·1	36·5	36·5	38·1	37·7	38·2
							36·5			

* Nos. 1, 2 and 10 constituted the

VII
weight

tion			Stigmatic end							Mean	Regional mean as percentage of pedicel value		
7	8	9	10	11	12	13	14	15	16		Pedicel	Middle	Stigmatic
70·2	70·0	68·6								68·8	100	106·0	104·5
	69·4												
82·5	81·7	79·3								79·9	100	104·5	104·3
	81·2												
72·0	69·1	68·2								70·7	100	104·6	100·3
	69·8												
73·1	70·6									73·2	100	104·2	102·0
–73·3													
72·4										73·7	100	102·5	100·5
·2													
										26·9	100	106·5	92·7
28·3										31·4	100	101·9	92·4
·4													
										35·0	100	103·1	97·5
31·5										34·3	100	104·0	96·5
·8													
30·5										31·6	100	101·2	84·3
·6													
25·7	25·2									26·6	100	105·0	98·0
–26·0													
25·8										27·5	100	102·9	96·0
·4													
										29·7	100	103·2	102·0
										30·8	100	100·3	96·8
										20·1	100	96·7	82·0
										27·1	100	102·6	98·2
26·3	24·9	22·8								26·7	100	100·0	89·0
	24·7												
25·6										27·7	100	103·2	94·2
·5													
31·7	29·4									32·9	100	96·5	90·7
–31·2													
22·9										26·0	100	104·7	93·5
·3													
14·9										19·4	100	95·7	76·4
·2													
23·8										25·6	100	103·5	95·6
·4													
35·9	36·4	35·1	34·5	33·4	31·9	30·0	28·6	26·1	25·0	32·6	100	105·3	84·3
		35·2					28·3						
36·8	37·3	34·4	33·8	32·9	32·6	30·4	27·4	27·0		34·0	100	100·5	84·1
	36·1					30·2							
38·0	37·8	35·6	35·2	32·7	31·9	27·8	27·8			34·8	100	98·3	85·3
	35·9				31·1								

samples for the main study.

TABLE

Seed-coat

No.	Name of cotton	No. of seeds in lock	Botanical species	Soil	Pedicel end				Posi-	
					1	2	3	4	5	6
1	Co 1 . . .	9	*G. hirsutum* .	Red	39·7	40·9	41·3	41·3	41·2	41·0
						40·6			41·2	
2	Co 2 . . .	9	Do. .	,,	42·5	43·8	43·3	43·2	41·3	41·7
						43·2			42·1	
3	Co 1 . . .	9	Do. .	,,	53·5	54·2	55·2	54·0	52·8	52·4
						54·3			53·1	
4	Do. . . .	8	Do. .	,,	54·0	55·1	55·1	53·6	52·9	51·3
						54·7		53·2		
5	Do. . . .	7	Do. .	,,	54·1	54·8	53·7	51·9	51·1	52·1
						54·4		52·2		50
6	2405 . . .	6	*G. herbaceum* .	Black	28·2	28·0	28·3	27·9	26·8	25·9*
						28·1	28·1		26·4	
7	2405 . . .	7	Do. .	Red	29·9	30·4	30·4	29·9	28·9	27·3
						30·2		29·7		26
8	2919 . . .	6	Do. .	Black	35·7	36·6	36·8	36·4	35·5	34·3
						36·2	36·6		34·9	
9	2919 . . .	7	Do. .	,,	35·7	36·6	37·5	37·1	36·1	35·3
						36·2		36·9		34
10	K 546 (Koilpatti)	7	*G. indicum* . .	Black	21·2	22·1	21·6	21·4	20·6	20·4
						21·6		21·2		20
11	K 546 (Coimbatore)	8	Do. . .	,,	23·6	23·7	23·7	23·8	23·5	23·0
						23·7		23·6		
12	Do. .	7	Do. . .	,,	23·5	24·7	23·7	23·5	23·3	22·5
						24·1		23·5		22
13	Do. .	6	Do. . .	,,	26·0	26·0	26·2	25·9	25·2	24·2
						26·0	26·0		24·7	
14	Do. .	5	Do. . .	,,	26·7	26·3	25·6	25·6	24·4	
						26·5	25·6	25·0		
15	N 14 . . .	6	Do. . .	,,	19·4	19·8	19·5	19·3	18·7	18·3
						19·6	19·4		18·5	
16	Do. . . .	6	Do. . .	Red	22·2	22·4	22·5	21·5	21·5	20·4
						22·3	22·0		21·0	
17	Verum early .	9	*G. neglectum* .	Red	23·8	24·1	22·6	22·5	21·7	21·8
						23·5			22·0	
18	Chandajari .	7	Do. .	,,	23·3	23·7	24·0	23·7	22·9	22·2
						23·5		23·5		21
19	Mollisoni . .	8	Do. .	,,	26·3	26·4	25·0	24·8	23·7	23·3
						25·9		24·2		
20	Nadam . .	7	*G. obtusifoleum* .	Red	24·7	25·3	24·9	25·0	24·4	23·7
						25·0		24·8		22
21	*G. sanguineum* .	7	*G. sanguineum* .	Black	18·9	19·3	18·5	18·1	16·9	16·6
						19·1		17·8		16
22	Do. .	7	Do. .	Red	20·1	20·5	19·8	19·6	18·7	17·9
						20·3		19·4		17
23	*G. cernuum* .	16	*G. cernuum* .	Red	41·8	44·0	44·1	44·9	42·7	44·0
							43·5			
24	Do.	15	Do. .	,,	44·8	46·6	46·2	46·1	45·0	44·9
							45·7			
25	Do. .	14	Do. .	,,	43·1	44·0	43·5	44·5	43·2	43·6
							43·7			

* For samples 1, 2 and 10 the seed-coat weight was determined after

VIII

weight

tion				Stigmatic end						Mean	Regional mean as percentage of pedicel value		
7	8	9	10	11	12	13	14	15	16		Pedicel	Middle	Stigmatic
40·6	40·0	39·8								40·6*	100	101·3	98·7
	40·1												
39·3	37·6	38·2								41·2*	100	97·5	89·0
	38·4												
50·3	48·5	47·7								52·0	100	97·7	90·0
	48·8												
49·9	48·8									52·6	100	97·0	91·4
–50·0													
49·4										52·4	100	95·8	93·3
·8													
										27·5	100	99·6	94·0
25·3										28·9	100	98·0	87·0
·3													
										35·9	100	101·1	96·4
33·1										35·9	100	101·9	91·7
·2													
20·3										21·1*	100	98·2	94·5
·4													
22·7	21·8									23·2	100	99·6	84·4
–22·5													
21·9										23·3	100	97·0	91·8
·2													
										25·6	100	100·0	95·0
										25·7	100	99·6	99·4
										19·2	100	99·0	94·5
										21·8	100	98·6	94·1
20·8	19·9	18·9								21·8	100	93·6	84·7
	19·9												
21·5										23·0	100	100·0	92·8
·8													
22·3	21·4									24·2	100	93·5	86·0
–22·3													
21·9										24·3	100	99·2	91·1
·8													
15·9										17·7	100	93·2	84·9
·2													
17·1										19·1	100	96·0	87·6
·5													
42·5	42·4	40·4	39·8	38·5	36·9	34·7	33·9	32·0	31·3	39·6	100	94·4	77·7
	41·1						33·8						
43·2	43·2	41·2	40·1	38·3	36·6	35·0	32·4	32·2		41·1	100	93·0	76·3
	42·5					34·9							
41·7	41·4	39·1	38·7	36·1	34·7	32·5	32·4			39·9	100	94·9	80·0
41·4					34·9								

removing the fuz by treating the seeds with sulphuric acid.

TABLE

Lint

No.	Name of cotton	No. of seed in lock	Botanical species	Soil	Pedicel end					Posi-
					1	2	3	4	5	6
1	Co 1 . . .	9	*G. hirsutum* .	Red	69·3	73·0	69·9	68·6	68·4	68·2
						70·7			68·4	
2	Co 2 . . .	9	Do. .	,,	80.6	82·2	77·5	77·7	75·8	75·6
						80·1			74·4	
3	Co 1 . . .	9	Do. .	,,	67·1	70·1	66·8	66·8	64·4	63·1
						68·0			64·8	
4	Do. . . .	8	Do. .	,,	75·0	77·4	73·1	73·4	72.9	69.4
						75·2		73·2		
5	Do. . . .	7	Do. .	,,	74·9	79·5	72·3	73·7	70·9	66·8
					77·2			72·3		65
6	2405 . . .	6	*G. herbaceum* .	Black	15·5	16·4	17·8	17·6	17·0	16·2*
					16·0		17·7		16·6	
7	2405 . . .	7	Do. .	Red	20·7	22·2	21·8	21·3	19·8	18·8
					21·4			21·0		18
8	2919 . . .	6	Do. .	Black	25·1	26·6	27·0	25·9	25·4	23·5
					25·8		26·4		24·4	
9	2919 . . .	7	Do. .	,,	25·1	26·4	27·4	26·9	25·4	25·1
					25·8			26·6		23
10	K 546 (Koilpatti)	7	*G. indicum* . .	Black	25·6	26·0	23·1	22·2	19·2	18·2
					25·8			21·5		17
11	K 546 (Coimbatore)	8	Do. . .	,,	24·9	26·1	25·1	24·4	21·8	21·1
						25·4		23·1		
12	Do. .	7	Do. . .	,,	26·8	27·2	25·2	24·2	21·8	20·9
					27·0			23·7		20
13	Do. .	6	Do. . .	,,	28·9	29·2	26·3	23·7	22·4	20·3
					29·0		25·0		21·4	
14	Do. .	5	Do. . .	,,	30·8	29·9	26·4	25·2	22·1	
					30·4		26·4	23·6		
15	N 14 . . .	6	Do. . .	,,	14·7	14·6	13·4	13·3	12·0	11·1
					14·6		13·4		11·6	
16	Do. . . .	6	Do. . .	Red	14·8	14·3	13·7	12·7	12·3	10·9
					14·6		13·2		11·6	
17	Verum early .	9	*G. neglectum* .	Red	25·0	25·8	22·7	22·5	20·3	19·4
						24·5			20·7	
18	Chandajari .	7	Do. .	,,	14·7	15·6	14·5	13·5	12·7	12·5
					15·1			13·6		11
19	Mollisoni . .	8	Do. .	,,	32·4	32·9	31·0	30·5	29·0	29·3
						32·1		29·8		
20	Nadam . .	7	*G. obtusifolium* .	Red	13·3	14·1	14·3	14·6	13·7	13·4
					13·7			14·2		13
21	*G. sanguineum* .	7	*G. sanguineum* .	Black	20·0	21·1	19·2	18·5	17·0	16·9
					20·6			18·2		16
22	Do. .	7	Do. .	Red	23·5	24·0	22·1	21·3	20·1	19·7
					23·8			21·2		19
23	*G. cernuum* .	16	*G. cernuum* .	Red	75·4	79·1	77·6	78·9	74·3	74·2
							77·1			
24	Do. .	15	Do. .	,,	82·8	87·4	83·8	84·0	79·5	79·9
							83·5			
25	Do. .	14	Do. .	,,	80·1	83·9	80·6	81·0	77·3	77·3
							80·6			

* Nos. 1, 2, and 10 constituted

IX

weight

tion			Stigmatic end							Mean	Regional mean as percentage of pedicel value		
7	8	9	10	11	12	13	14	15	16		Pedicel	Middle	Stigmatic
67·9	65·6	64·7								68·4	100	96·8	93·5
	66·1												
73·7	66·4	65·2								75·0	100	92·8	85·4
	68·4												
61·9	57·3	55·3								63·6	100	95·3	85·5
	58·2												
66·3	60·6									71·0	100	97·4	87·0
65·4													
63·4										71·6	100	93·6	84·4
·1													
										16·6	100	111·3	103·8
17·5										20·3	100	98·2	85·0
·2													
										25·6	100	102·3	94·5
22·4										25·5	100	103·0	92·2
·8													
17·1										21·6	100	83·4	68·2
·6													
19·6	19·0									22·7	100	91·0	78·4
19·9													
19·3										23·6	100	87·7	74·5
·1													
										25·1	100	86·3	73·8
										26·9	100	86·8	77·6
										13·2	100	91·7	79·4
										13·1	100	90·3	79·4
18·3	16·7	14·9								20·6	100	81·1	65·0
	16·6												
11·0										13·5	100	90·0	78·2
·8													
27·4	25·6									29·8	100	92·8	85·3
27·4													
12·5										13·7	100	103·7	95·0
·0													
15·2										18·3	100	88·4	77·7
·0													
18·3										21·3	100	89·0	79·7
·0													
74·0	73·0	70·1	68·3	65·2	62·3	59·1	55·4	48·6	45·6	67·6	100	91·8	70·2
	70·8						54·2						
76·3	73·9	72·3	69·1	65·6	63·4	59·8	55·2	50·4		72·2	100	89·0	70·5
	74·3					58·9							
74·8	77·2	65·1	66·1	63·0	60·1	54·4	50·4			70·8	100	91·2	73·0
73·6					58·8								

the samples for the main study.

TABLE

Ginning

No.	Name of cotton	No. of seed in lock	Botanical species	Soil	Pedicel end 1	2	3	4	5	6 (Posi)
1	Co 1 . . .	9	*G. hirsutum* .	Red	37·4	38·1	36·4	35·7	35·5	35·1
						37·5			35·4	
2	Co 2 . . .	9	Do. .	,,	37·1	37·1	35·7	35·5	35·4	34·8
						36·6			35·2	
3	Co 1 . . .	9	Do. .	,,	36·2	36·6	35·3	35·4	34·9	34·4
						36·0			34·9	
4	Do. . . .	8	Do. .	,,	37·8	37·6	36·0	36·3	36·2	35·6
						37·1		36·2		
5	Do. . . .	7	Do. .	,,	37·4	38·2	36·0	37·1	36·4	35·4
					37·8			36·5		34
6	2405 . . .	6	*G. herbaceum* .	Black	22·8	23·2	24·1	24·2	25·3	25·6
					23·0		24·2		25·4	
7	2405 . . .	7	Do. .	Red	25·4	26·3	25·9	25·8	24·7	24·8
					25·8			25·5		24
8	2919 . . .	6	Do. .	Black	26·6	27·3	27·5	26·6	27·0	26·8
					27·0		27·0		26·9	
9	2919 . . .	7	Do. .	,,	27·1	27·4	27·3	27·0	26·5	26·8
					27·2			26·9		26
10	K 546 (Koilpatti)	7	*G. indicum* . .	Black	32·2	32·0	29·9	29·2	26·7	25·8
					32·1			28·6		25
11	K 546 (Coimbatore)	8	Do. . .	,,	32·9	33·5	32·1	31·7	29·2	28·9
						32·8		30·4		
12	Do. .	7	Do. . .	,,	34·6	34·3	32·7	31·7	29·7	29·4
					34·4			31·4		29
13	Do. .	6	Do. . .	,,	37·4	34·5	32·0	30·0	29·6	28·4
					36·0		31·0		29·0	
14	Do. .	5	Do. . .	,,	35·0	33·9	31·4	30·4	28·4	
					34·4		31·4	29·4		
15	N 14 . . .	6	Do. . .	,,	26·5	26·1	24·9	25·1	24·9	24·2
					26·3		25·0		24·6	
16	Do. . . .	6	Do. . .	Red	23·0	22·5	21·5	20·7	20·3	19·4
					22·8		21·1		19·8	
17	Verum early .	9	*G. neglectum* .	Red	32·7	33·2	30·8	30·7	29·5	28·5
						32·2			29·6	
18	Chandajari .	7	Do. .	,,	22·8	23·5	21·8	20·7	20·3	20·2
					23·2			20·9		19
19	Mollisoni . .	8	Do. .	,,	35·1	35·6	34·8	34·2	33·9	34·4
						35·2		34·0		
20	Nadam . .	7	*G. obtusifolium* .	Red	21·1	21·5	21·5	21·8	21·3	21·7
					21·3			21·5		22
21	*G. sanguineum* .	7	*G. sanguineum* .	Black	34·2	34·1	32·8	32·4	32·2	33·1
					34·2			32·5		33
22	Do. .	7	Do. .	Red	34·4	34·5	32·4	31·4	30·9	31·4
					34·4			31·6		31
23	*G. cernuum* .	16	*G. cernuum* .	Red	50·7	50·5	49·2	49·8	48·2	48·3
							49·5			
24	Do. . .	15	Do. . .	,,	50·6	51·3	50·0	49·8	48·3	48·6
							50·0			
25	Do. . .	14	Do. . .	,,	50·8	51·7	50·2	49·2	48·5	48·8
							50·1			

* Nos. 1, 2 and 10

X

percentage

tion		Stigmatic end								Mean	Regional mean as percentage of pedicel value		
7	8	9	10	11	12	13	14	15	16		Pedicel	Middle	Stigmatic
35·6	35·2	34·9								36·0	100	94·9	94·3
	35·2												
34·9	33·1	32·5								35·1	100	96·2	91·5
	33·5												
34·7	34·2	33·2								35·0	100	96·8	94·5
	34·0												
35·3	33·5									36·1	100	96·6	94·0
–34·8													
34·4										36·5	100	95·7	94·0
·9													
										24·2	100	105·2	110·3
24·8										25·2	100	98·8	96·1
·8													
										27·0	100	100·0	99·6
26·8										27·0	100	99·0	98·5
·8													
25·4										28·7	100	86·0	79·7
·6													
28·3	28·0									30·6	100	92·6	86·5
–28·4													
28·7										31·6	100	91·2	81·3
·0													
										31·6	100	86·1	80·6
										31·8	100	91·3	85·5
										25·3	100	95·0	93·5
										21·2	100	92·5	86·8
27·8	27·6	26·6								29·7	100	92·0	84·8
	27·3												
19·6										21·3	100	90·0	85·8
·9													
34·0	34·1									34·5	100	96·6	97·0
–34·2													
22·2										21·6	100	101·0	103·2
·0													
33·6										33·2	100	95·0	96·6
·4													
31·0										32·3	100	92·0	90·7
·2													
48·1	47·6	47·8	47·2	46·7	47·4	47·4	47·3	45·6	44·7	48·4	100	96·1	94·0
	47·6						46·5						
48·6	47·7	48·0	48·5	47·3	47·0	46·9	47·2	46·5		48·5	100	96·6	94·0
	48·3					47·0							
48·3	49·2	46·2	47·7	46·6	47·3	48·0	45·2			48·7	100	95·7	94·0
48·0					47·2								

constituted the samples for the main study

§II. Fibre characters

In § I the seed and lint characters were considered. The fibre characters will be dealt with in the following :—

(*a*) *Fibre length*

The results are recorded in Table XI.

TABLE XI

Mean fibre length in inches

Position of seed	Co 1	Co 2	K 546
Pedicel end—			
I	1·02	1·00	0·96
II	1·02	1·00	0·98
III	1·04	1·03	1·03
IV	1·02	1·02	1·02
V	1·03	1·02	1·01
VI	1·04	1·04	0·99
VII	1·04	1·06	0·95
VIII	1·04	1·05	..
IX	1·02	1·06	..
Stigmatic end—			

In Co 1 there does not appear to be much fluctuation. In Co 2 the first seed has the shortest length and the last seed the longest, the increase appearing to be gradual in the intermediate positions. In K 546 also the differences are large though the trend of variation is different. There is an increase in length up to the middle of the lock followed by a gradual fall later. The variability in this strain bears resemblance to that observed by Ayyar and Rao [1930] in the case of another *indicum* cotton, N 14. The variation in Co 1 also corresponds with that found by them except in the last position. Armstrong and Bennett [1933] also have noted an increase of length up to about the middle of the lock with a fall later. Sen [1932], however, does not find any significant difference.

It is clear from the foregoing that in some strains definite differences do exist among the positions in a lock. In breeding work, where the halo length is measured on a few seeds only, it becomes imperative that the effect of this factor, which is considerable, is to be eliminated. Hence the seeds of a definite position in the lock have to be selected.

(*b*) *Fibre weight*

The results for this property which were obtained for the different group-lengths for the various positions have been studied by the method of analysis of variance. The variance values are given in the appendix and the mean values* are given in Table XII.

TABLE XII

Fibre weight per cm. in 10^{-6} *gm.*

Position of seed	Co 1	Co 2	K 546
Pedicel end—			
I	2·16	2·17	2·67
II	2·06	2·05	2·50
III	1·99	1·99	2·33
IV	2·01	1·98	2·32
V	1·97	1·98	2·20
VI	1·98	2·01	2·24
VII	2·04	2·02	2·19
VIII	2·05	1·98	..
IX	1·97	2·07	..
Stigmatic end—			
Critical difference for $P = 0·05$.	0·043	0·046	0·047

The first position has the highest weight in all the three strains. The variations among the other positions are not considerable in Co 1 and Co 2, while in K 546 there appears to be a steady fall with advance of position. The difference between the extreme values is 8 per cent in the Cambodias, while it is 18 per cent in K 546. Sen [1932] also finds the lowest weight in the stigmatic end and highest at the pedicel end.

The variance table (appendix) shows that for Co 1 and Co 2 the variance between positions accounts for a small portion of the total, while for K 546 it accounts for a good deal. All variances are, however, significant for the one per cent level of significance. The critical difference calculated both according to the residual and interaction errors denoted that many differences for K 546 and some for Co 1 and Co 2 are significant.

* The arithmetic means got in the analysis of variance are given here in place of the weighted means. But this does not modify any of the conclusions drawn, as very little difference was found to exist between the two means.

(*c*) *Unit fibre weight*

The values are given in Table XIII.

TABLE XIII

Unit fibre weight in 10^{-6} gm.

Position of seed	Co 1	Co 2	K 546
Pedicel end—			
I	5·54	5·53	6·58
II	5·29	5·18	6·35
III	5·12	5·13	6·15
IV	5·18	5·00	6·06
V	5·10	5·08	5·67
VI	5·15	5·26	5·68
VII	5·31	5·30	5·33
VIII	5·34	5·17	..
IX	5·02	5·44	..
Stigmatic end—			

In Co 1 and Co 2 there does not appear to be much variation, except that the first seed records the highest weight. In K 546 there is almost a steady fall with the advance of position.

(*d*) *Number of fibres per seed*

The values are given in Table XIV.

TABLE XIV

Number of fibres per seed

Position of seed	Co 1	Co 2	K 546
Pedicel end—			
I	12,890	15,040	3,990
II	14,250	16,270	4,220
III	14,000	15,370	3,870
IV	13,640	15,910	3,770
V	13,810	15,300	3,490
VI	13,640	14,810	3,320
VII	13,240	14,220	3,300
VIII	12,680	13,170	..
IX	13,270	12,340	..
Stigmatic end—			

In all the three strains, after a preliminary rise from the first to the second position there is a continuous fall towards the end of the lock. The trend of variation, however, is not so marked in Co 1 as in the other two strains.

(e) *Number of fibres per unit area of the seed*

The figures obtained by dividing the number of fibres got above by the surface area found previously are given in Table XV.

TABLE XV

Number of fibres per unit area of the seed surface, in arbitrary units

Position of seed	Co 1 ($\times 1/k$)	Co 2 ($\times 1/k^1$)	K 546 ($\times 1/k^1$)
Pedicel end—			
I	7,530	8,750	4,990
II	7,830	8,790	5,020
III	7,650	8,440	4,660
IV	7,750	8,510	4,710
V	7,680	8,230	4,360
VI	7,550	7,970	4,150
VII	7,320	7,860	4,070
VIII	7,040	7,180	..
IX	7,250	7,020	..
Stigmatic end—			

The trend of variation appears to be nearly parallel to that found in the case of the total number of fibres on the whole seed, except that the divergences noted between the first and second positions are levelled up and the fall is more continuous. It, therefore, follows that the variations observed are more due to the density of the fibre population than to the surface area.

(f) *Immaturity*

As in the case of the fibre weight, these results were also studied by the method of analysis of variance. The variances are given in the appendix and the mean values in Table XVI.

The absence of results for some of the positions acts as a handicap against drawing definite conclusions in strains Co 2 and K 546. In Co 1 for which results for all the positions are available, no regular trend of variation is apparent.

The variances are significant in all the strains, for all the three types of fibres. The interaction variance is also significant in almost all cases, indicating the existence of a differential response of position of seed to causing immaturity among the different lengths of fibres.

TABLE XVI

Maturity percentage

Position of seed	Ripe fibres			Dead fibres			Thin-walled fibres		
	Co 1	Co 2	K 546	Co 1	Co 2	K 546	Co 1	Co 2	K 546
Pedicel end—									
I	72·6	...	...	11·6	...	...	15·8	...	...
II	78·8	61·7	...	8·4	17·8	...	12·8	20·6	...
III	71·1	...	79·2	12·2	...	11·0	16·7	...	9·8
IV	68·5	51·2	85·7	11·9	33·9	8·3	19·6	14·9	6·0
V	59·7	...	75·5	21·0	...	14·9	19·3	...	9·6
VI	64·4	55·9	...	17·7	25·0	...	17·9	19·1	...
VII	69·0	...	80·4	12·4	...	10·7	18·6	...	8·9
VIII	66·4	59·6	...	16·8	20·5	...	16·9	19·9	...
IX	66·2	...	...	11·7	...	...	22·1	...	...
Stigmatic end—									
Critical difference for $P =$ 0·05	2·8	3·2	2·9	2·4	3·6	1·8	2·5	3·2	2·4

INTER-RELATIONSHIPS

The data obtained may be utilized for the study of the inter-relationships among the several characters. This knowledge will enable us to get a better insight into the factors governing the lint index and ginning percentage among seeds developing under conditions obtaining in a lock, where the influences of soil, weather, age of plant, etc. do not enter.

The study of the correlation coefficient is the method adopted. It should, however, be pointed out, at the outset, that the application of this method to the present case is open to the objection that the variables do not satisfy one of the three conditions essential in the simple sampling of attributes. As the seeds are situated within a lock, the individual values of any character are not completely independent of one another. Again, if the interpretation of the correlation coefficient is to be correct, the regression lines must be proved to be linear. As the number of pairs of values (nine for Co 1 and Co 2 and seven for K 546) are small the test of linearity will be of doubtful significance. Hence the conclusions that can possibly be drawn from the values of the correlation coefficient should be taken, at best, as approximate indices showing the general trend of association only. The values of the coefficients are given in Table XVII.

Taking the seed weight first and comparing it with its components, the embryo weight and seed-coat weight, it is seen that the association * in both cases is positive, showing that the growth of the whole is consequent on the growth of both the parts. The area of seed surface, the number of fibres produced on the seed, the density of the fibre population (except in Co 1) and the lint weight (also excepting in Co 1) are also found to be positively associated.

* By association is meant that the two properties vary in the same direction though the correlation coefficient may not be significant.

The lint weight was stated above to be positively associated with the seed weight. The association with its components may now be considered. Whereas with the embryo weight the association is negative in Co 1 and Co 2 and positive in K 546 (all not significant), the correlation coefficient of the lint weight with the seed-coat weight is positive in all the three cottons and significant in two of them. This means that the lint and seed-coat follow a similar line of development which is different from that followed by the embryo.

Comparing the lint weight with its own component parts, it is found to be associated to a greater extent with the number of fibres per seed than with the unit fibre weight in the Cambodia strains, while in K 546 it is equally associated with both. Coming to the further sub-divisions of the whole fibre, it is found that there is hardly any association except for two cases—in K 546 the lint weight is positively and significantly correlated with the weight per unit length and in Co 2 it is similarly but negatively correlated with the length of the fibre.

The association of the ginning percentage with the seed weight is found to be negative in Co 2 but positive in the other two cottons. But it has been found by previous workers that, as a general rule, a higher ginning percentage is associated with lower seed weight. Turner [1929, 2] from his own data as well as that got from Balls comes to this conclusion. Dunlavy [1933] and Kearney [1926] report likewise, the values of the correlation coefficient obtained by them being —0·53 and —0·43 respectively. Griffee *et al.* [1929] got —0·112 as the value of the correlation coefficient in 18 American Upland varieties. Among the seeds in a lock, however, this does not appear to be the case. In only two cases out of the 25 cottons is the association negative. In five of them the correlation coefficient is significantly positive and in one of them highly so.

The ginning percentage is positively related to the number of fibres per seed and the association is still better with the density of the fibre population on the seed. This is in agreement with the statement of Balls [1930], ' whatever minor factors may be involved that the major determinant of the ginning out-turn is the number of hairs per seed.' Higher out-turn is also associated with the better development of the fibre., viz. fibre weight per cm.

Taking the unit fibre weight and its components, it is found to be highly related to the weight per unit length, having almost nothing to do with the length of the fibre.

Conclusions

(1) The mean fibre length is nearly constant in Co 1. In Co 2 it rise gradually from the first position to the last, while in K 546 it rises up to about the middle of the lock and falls later on.

(2) The fibre weight per cm. does not indicate any variation in Co 1 and Co 2, except for a higher value in the first position. But a consistent fall from first to last position is noted in K 546.

(3) The unit fibre weight shows no variation in Co 1 and Co 2, but exhibits a gradual fall in K 546.

(4) The number of fibres per seed as well as the number per unit area gradually decreases towards the end of the lock. The rise noted from the first to the second position in the former character is absent in the latter.

TABLE

Correlation

Properties correlated	Lint weight			Ginning percentages			Embryo weight			Seed-coat weight			Fibre
	Co 1	Co 2	K 546	Co 1	Co 2	K 546	Co 1	Co 2	K 546	Co 1	Co 2	K 54	Co 1
Seed weight . . .	—·28	+·60	+·77	—·60	+·47	+·74	+·82	+·45	+·66	+·32	+·71	+·79	+·52
Lint weight . . .				+·76	+·87	+·83	—·34	—·37	+·46	+·45	+·83	+·77	—·19
Ginning percentage .							—·68	—·46	+·42	+·02	+·78	+·76	—·8[illegible]
Embryo weight . .										+·39	—·36	+·70	+·53
Seed-coat weight . .													+·20
Fibre length . .													
Fibre weight . . .													
Number of fibres . .													
Unit-fibre weight . .													
Area													

Value for significance ($P = 0{\cdot}05$) is $0{\cdot}67$

XVII

coefficients

length		Fibre weight per unit length			No. of fibres			Unit fibre weight			Area			No. of fibres / area		
Co 2	K 546	Co 1	Co 2	K 546	Co 1	Co 2	K 546	Co 1	Co 2	K 546	Co 1	Co 2	K 546	Co 1	Co 2	K 546
−·31	+·36	−·71	−·16	+·57	+·27	+·71	+·78	−·58	−·39	+·73	+·42	+·41	+·43	+·04	+·56	+·77
−·76	+·07	+·25	+·33	+·77	+·63	+·84	+·84	+·24	−·10	+·81	−·08	+·05	+·41	+·74	+·88	+·85
−·78	+·05	+·55	+·42	+·78	+·32	+·79	+·84	+·50	−·05	+·81	+·28	+·02	+·43	+·51	+·87	+·85
+·59	+·56	−·66	−·71	+·11	+·01	−·19	+·55	−·52	−·42	+·31	+·59	+·49	+·52	−·02	−·42	+·49
−·73	+·27	−·49	+·20	+·55	+·71	+·83	+·81	−·41	−·26	+·64	+·26	+·33	+·60	+·63	+·83	+·76
		−·32	−·44	+·26	−·37	−·71	+·09	−·08	+·10	+·02	−·14	+·04	+·08	−·34	−·79	+·08
					+·17	+·06	+·71	+·85	+·72	+·80	−·69	−·66	+·21	−·04	+·31	+·75
								−·44	−·45	+·76	+·30	−·21	+·51	+·76	+·84	+·84
											−·62	−·77	+·22	−·11	−·17	+·80
														−·11	+·11	+·35

for Co 1 and Co 2 and 0·75 for K 546.

(5) The variation in the maturity cannot be assessed definitely on account of the absence of complete data.

(6) A study of the inter-relationships among the different characters discloses the following points :—

(*a*) The seed weight is positively associated with many of the characters, reflecting the general trend of all-round growth.

(*b*) The lint weight is more prominently associated with the number of fibres per seed than with the weight of the whole fibre in both Co 1 and Co 2. In K 546, however, it is equally associated with both.

(*c*) The ginning percentage is strongly associated with the lint weight. The negative correlation of the ginning percentage with seed weight, generally reported by different workers among different varieties, is not confirmed in the present case among seeds within a lock.

(*d*) The unit fibre weight is more dependent on the weight per unit length than on the length of the fibre.

ACKNOWLEDGEMENTS

The writer's best thanks are due to Rao Bahadur V. Ramanatha Ayyar for suggesting the problem and for considerable interest in the work and for valuable advice. He is indebted to late Mr. P. Gopalaratnam for the weights of *G. cernuum* and to the assistants of the Cotton Specialist's section for determining the weights of some of the strains and for the help rendered in the calculation of some of the variances. The work was done under the financial assistance of the Indian Central Cotton Committee.

REFERENCES

Abraham, P. and Ayyar, V. R. (1937). *First conference of scientific workers on cotton in India, 1937*, p. 371
Armstrong, G. M. and Bennett, C. J. (1933). *J. agric. Res.* **47**, 447-76
Ayyar, V. R. and Rao, C. J. (1930). *agric. J. India* **25**, 42-52
Balls, W. L. (1930). *Min. Agric. Egypt Tech. and Sci. Bull.* No. **101**, 15
Dunlavy, H. (1923). *J. Amer. Soc. Agron.* **15**, 444-8
Griffee, F. *et al.* (1929). *Oklahama Expt. Sta. Bull.* **187**
Iyengar, R. L. N. (1929). *Madras Agric. Dept. Yearbook, 1929*, 7-15
Iyengar, R. L. N. and Turner, A. J. (1930). *Ind. Cent. Cot. Com., Tech. Lab. Tech. Bull. Ser. B.* No. **7**
Iyengar, R. L. N. (1939). *Indian J. agric. Sci.* **9**, 305-29
Kearney, T. H. (1926). *J. agric. Res.* **33**, 781-96
Sen, K. R. (1932). *Indian J. agric. Sci.* **2**, 484-98
Turner, A. J. (1929, 1). *agric. J. India* **24**, 83-90
Turner, A. J. (1929, 2). *Ind. Cent. Cot. Com. Tech. Lab., Tech. Bull. Ser. B* No. **4**

APPENDIX

Analysis of variance

Property	Cotton	Variance due to	Degrees of freedom	Mean square
Fibre weight per cm. in 10-6 gm.	Co 1	Positions	8	0·1500*
		Lengths	4	1·4310*
		Residual	315	0·00416
	Co 2	Positions	8	0·1560*
		Lengths	4	1·9818*
		Residual	315	0·00503
	K 546	Positions	6	1·2458*
		Lengths	4	0·4553*
		Residual	245	0·00572
Ripe fibres percentage	Co 1	Positions	8	1461·63*
		Lengths	4	1886·18*
		Residual	405	25·84
	Co 2	Positions	3	636·60*
		Lengths	4	915·96*
		Residual	100	20·64
	K 546	Positions	3	622·77*
		Lengths	4	3772·60*
		Residual	120	19·91
Dead fibres percentage	Co 1	Positions	8	766·13*
		Lengths	4	409·26*
		Residual	405	17·41
	Co 2	Positions	3	1493·40*
		Lengths	4	702·06*
		Residual	100	25·05
	K 546	Positions	3	261·22*
		Lengths	4	2212·84*
		Residual	120	7·65
Thin-walled fibres percentage	Co 1	Positions	8	347·75*
		Lengths	4	582·53*
		Residual	405	19·73
	Co 2	Positions	3	196·30*
		Lengths	4	92·94*
		Residual	100	20·00
	K 546	Positions	3	108·38*
		Lengths	4	237·58*
		Residual	120	12·00

* Significant for $P = 0{\cdot}01$

STUDIES ON PROPAGATION OF THE MANGO, *MANGIFERA INDICA* L.

BY

K. C. NAIK, B.Ag. (Bom.), M.Sc. (Bristol)

Superintendent, Fruit Research Station, Kodur P. O., Cuddappah District

(Received for publication on 15 November 1940)

(With Plates XXXVIII and XXXIX)

INARCHING in the case of superior varieties and seed propagation in the case of others have been the commonest mango nursery practices in India for centuries. Of late, a number of workers in India have experimented upon the possibility of raising mangoes by other vegetative methods, chiefly by shield budding. Owing partly to regional variations in regard to climate and cultural practices and partly to the relatively small-scale trials or the unsystematic nature of these trials, the published results of such investigations are either scarce or inconclusive, and the extent of success obtained has been very varying, and generally poor.

Inarching, though easy in practice, is a more expensive method than budding, and according to some workers [Fielden and Garner, 1936] is only suitable for countries where labour is cheap. It has also been asserted that trees propagated by inarching are often short-lived or stunted—results which are being now attributed to the operation of inarching itself instead of to the cutting off of the tap-root as was formerly believed [Fielden and Garner, 1936]. According to Paul and Guneratnam [1937] budded plants have proved to be more vigorous in growth than inarched or cleft-grafted plants in Ceylon. Above all, inarching can only be performed at reasonable cost where scion parent is growing in the close vicinity of the nursery, whereas budding, side-grafting and such other vegetative methods are possible even with scion wood obtained from a distance. Widespread use of vegetative methods other than inarching is therefore desirable for a variety of reasons.

Popenoe [1927] has recorded that it is not a simple matter to bud mangoes successfully and adds that only a few propagators in the United States of America are able to produce budded mango trees economically and in quality. Woodrow [1904] made many attempts in India to bud mango, but without any success. After some trials in Poona, Burns and Prayag [1906] came to the conclusion that 'mango budding is yet an uncertain means of propagation'. They also refer to the report of similar lack of success from the trials in Saharanpur and Nagpur. Higgins [1906] and Paul and his associates [1937] were, however, able to obtain a high success by budding in Hawaian Islands and Ceylon respectively, while in Porto Rico [Popenoe, 1927] crown-grafting was found to be more successful than budding. In Java nearly 90 per cent success is reported for the modified Forkert method of budding [Fielden and Garner, 1936]. Wray [1939] reports to have top-worked in

Jamaica over 1,000 mango trees by budding, but he does not mention the extent of success obtained.

Among methods of vegetative propagation other than budding and inarching which have recently merited attention in so far as mango is concerned, side-grafting and mound layering through ringing of etiolated shoots are the most important. Success by side-tongue grafting has been reported from Hawaii [Fielden and Garner, 1936] and by ordinary side-grafting with pre-cured scions by Nakamura [Tanaka, 1939]. Fielden and Garner [1936] quoting the experiments in Java consider it possible to raise rootstock seedlings vegetatively by ring-barking and eticlating the ringed parts so as to induce rooting therein. Whip grafting, saddle grafting, wedge grafting, embryo grafting, rooting of cuttings, and marcotting have also been tried with little or no success in different lands, but none of these has had a wide application in commercial nursery practice [Fielden and Garner, 1936]. The available results from these trials afford justification for the hope that some of these methods at least may be so improved in technique as to render it possible to replace in a large measure the prevalent practices of mango propagation by seed and inarching. It is on these grounds that further research on most of the above-mentioned various propagational methods in an important mango-producing province as that of Madras is justified.

On the basis of the work of a number of people, Hatton [1932] has proved that seedling rootstock in mono-embryonic fruits furnishes a very variable material. Where rootstocks cannot be raised vegetatively, polyembryony has been shown to be a great advantage in securing uniform rootstocks from seed [Hatton, 1932, Fielden and Garner, 1936]. Popenoe [1927] has surmised that although the seedling races of the tropics are polyembryonic in character, most of the grafted Indian varieties have lost this characteristic and seedlings from these differ from their parents as does a seedling peach. On the authority of Belling, Fielden and Garner [1936] have pointed out that broadly speaking, the choice mangoes of the East Indies and Philippines are polyembryonic, while the Indian varieties are mono-embryonic, and the former reproduce themselves true from seed to such a remarkable extent that it may be assumed that the fertilized embryo is often absent. Sen and Mallik [1940] have found that multiple shoots with only a single tap-root occur occasionally in the germinating seeds of Bombai, Langra and Fazli varieties of mangoes in Bihar. Such observations have formed the common experience of nurserymen in South India as well, and may have given rise to the erroneous belief entertained by some that most of the cultivated mangoes of India are polyembryonic. The discovery of polyembryonic mangoes for obtaining a pure line of vegetatively produced descendants to serve as uniform seedling rootstock, as is being done in citrus [Hatton, 1932], instead of the variable material from mono-embryonic mango varieties as is done at present in India is, therefore, a work of considerable scientific and practical importance.

After a very comprehensive review of literature on root-stock and scion relationship, Swarbrick [1930] infers that the 'stem-piece of the rootstock may have as much influence in determining what is known as "rootstock influence" as the actual absorbing root-system'. He refers to the earlier work of Roberts and himself in the United States of America and the conclusion arrived at from their investigations [1927] that a large amount of the uniformity

obtained by the use of vegetatively propagated rootstocks is in the first place due to selection, and in the second to the use—in effect—of a uniform intermediate stem-piece. Swarbrick concludes that 'greater uniformity of tree growth and performance would be obtained by eliminating such stem pieces when grafting seedlings'. He also adds that 'greater uniformity should result from double-working, particularly if the first working takes the form of bench grafting on to root pieces'. Knight [1927] and Grubb [1925] have also shown that the stem-piece of a rootstock was an important item in the ultimate effect of rootstock upon scion. Bench-grafting which is popular in the United States of America and is also becoming popular in England and Australia [Whittaker, 1940] is supposed by Swarbrick [1930] to eliminate all stem influence but that of the scion itself. He adds that 'there is no validity in the *a priori* assumption that use of miscellaneous seedlings will give miscellaneous results', and that, ' the claims of the seedling rootstock deserve the same systematic attention and investigation that is being given to the vegetatively propagated rootstocks'. The mango rootstock which is only seed-propagated in India does not therefore require a stronger plea than the above for its demand on the attention of the workers in this country. Since vegetative methods of propagation of mango rootstock have not so far been successfully devised at least to an extent as to warrant their adoption on a commercial scale in mango nursery trade, and since according to Swarbrick [1930] great uniformity in seedling rootstocks can be obtained by the elimination of stem-piece of the rootstock in the budded or grafted plant, the need for exploring the value of employing only the root-piece of the seedling rootstock in mono-embryonic mangoes of India will not require over-emphasis.

The investigations reported in the present paper were designed to determine firstly, the optimum season and technique for mango propagation by the prevalent methods of inarching in due regard to the regional requirements, secondly, to discover one or more methods of vegetative propagation which can advantageously replace the commonly adopted method of inarching, thirdly, to find out if any polyembryonic mangoes exist in this part of India and, if so, what their value as rootstocks to superior cultivated mango varieties are, and fourthly, to explore the possibility of imparting uniformity to seedling rootstocks from mono-embryonic parents through root-grafting and double-working on the lines advotcated by Swarbrick [1930].

Experimental

The experiments reported in these pages were initiated in 1935 and were in progress thereafter for a period of about five years. As they comprised of several independent investigations, and facilities could not become available for undertaking of all these at one time, the actual period of work on each independent problem, as will be shown later, has varied greatly, depending upon the facilities and the importance of the investigation. For these reasons and for the sake of clarity, it is considered appropriate to present the report on each propagational method separately along with the materials and methods under each.

Polyembryony

The district of Malabar claims the largest acreage under mangoes in the Madras province. Almost the entire mango crop in this district is produced by seedling trees, and despite this fact, the produce is believed to be remarkably uniform to an extent met with in vegetatively propagated orchards. Some of the seedling trees in this district and in the neighbouring tracts of South Kanara have also enjoyed the reputation of being very precocious, producing crops within three or four years of sowing. These facts led to the belief that most of the mangoes grown in these regions may be polyembryonic, and this assumption was further strengthened from the reports received from some of the growers and agricultural departmental workers in the West Coast, chiefly from Mr E. K. Govindan Nambiar, Farm Manager of Talliparamba Agricultural Research Station.

In view of the great importance and value of polyembryonic mangoes in the work of standardization of seedling rootstocks and of the difficulties encountered all over the world in the vegetative propagation of rootstocks, a study of these South Indian mangoes for testing their polyembryonic character was thought necessary. Accordingly, during the mango season in 1937, 246 seeds from 11 trees of apparently eight different races of polyembryonic mangoes were collected in the West Coast and sown in the nurseries of the Fruit Research Station, Kodur. The seedlings were lifted and potted during the following October, and a careful and detailed count of the number of seedlings obtained from each seed was made.

The total number of seedlings obtained out of the 129 germinated seeds were 218, and the maximum number of seedlings got from one seed were four in Kurkan and Olour varieties. These preliminary observations were sufficient to establish clearly the polyembryonic character of these West Coast mangoes. Incidentally, it was observed that after potting of these seedlings, the casualties amounted to only seven seedlings. This fact not only strengthens the polyembryonic character of these races, but also indicates that transplanting of these mango seedlings with naked roots, necessitated by detailed examination of their polyembryonic character, is a feasible nursery operation.

A fresh collection of seed material was made during the mango season in 1938 in the course of a tour in the West Coast. As a result, 1,024 stones of ten apparently different polyembryonic varieties were collected and sown at Kodur during April and May 1939, and 800 stones of five of these varieties were also supplied to Horticultural Research Station, Sabour (Bihar), for study there.

The seedlings obtained from the material sown in 1939 at Kodur were lifted and potted during September 1939. The data recorded from an examination of these seedlings on that occasion are tabulated in Table I.

It is observed that the maximum number of seedlings obtained per seed has been as many as five in Kurkan No. 2 variety, and four in Bellary, Olour, Kurkan No. 1, and Goa. On the basis of seedling count on germinated seeds, it is found that Kurkan No. 1 and 2 appear to be most highly polyembryonic and Muvandan the least, excluding, however, the mixed lot from Calicut.

TABLE I

Actual number of seedings obtained from 10 different varieties of polyembryonic mangoes during 1939

Variety	No. of stones sown	No. of seeds from which the seedlings obtained were at the rate of					Total No. of seedlings obtained	Ratio seedlings / germinated seeds	Percentage of germination	Seedlings as per cent of seeds sown
		One each	Two each	Three each	Four each	Five each				
1. Neelaparanky	97	10	12	5	...	...	49	1·8	27·8	50·5
2. Bellary	100	27	17	11	5	...	114	1·9	60·0	114·0
3. Olour	90	12	7	3	1	...	39	1·7	25·6	43·3
4. Mylipelian	116	44	14	6	...	...	90	1·4	55·2	77·6
5. Chandrakaran	24	12	4	...	...	...	20	1·3	66·7	83·3
6. Muvandan	21	5	1	...	...	...	7	1·2	28·6	33·3
7. Mixture of Salen, Kumbran and Neelaparanky from Calicut	184	15	1	...	...	...	17	1·1	8·7	9·2
8. Kurkan, K-1	75	4	5	3	1	...	27	2·1	17·3	36·0
9. Kurkan, K-2	95	10	14	6	...	1	61	2·0	32·6	64·2
10. Goa	205	33	18	8	5	...	113	1·8	31·2	55·1

It is commonly believed that polyembryonic mangoes, in general, give very poor germination. This statement is probably true in most of the varieties tested, but it certainly does not hold good in Bellary, Chandrakaran and Mylipelian varieties. If the actual number of seedlings obtained are taken into consideration, it will be seen that Kurkan No. 1, Muvandan and Olour are perhaps the only varieties which are not likely to appeal to the mango nurserymen, and Bellary would be the most favoured.

Seed propagation

A. Method of sowing

It is known to mango nurserymen in India that a varying number of mango seedlings possess crooked stems which render them unfit for use as rootstocks for inarching. For the purpose of root-grafting also (a method which will be described elsewhere) it is essential that the rootstock seedling should have a straight piece of tap-root close to the collar. It is observed that the mango seedling in the initial process of its emergence through the soil is susceptible to make a detour when the least impediment occurs by way of a small gravel or any other solid piece in the soil above the seed in the path of the growth and emergence of the seedling out of the soil. In most cases, it is also found that a loop is formed on the stem of the young seedling as a result of the difficulty experienced at the time of emergence of the growing tip from the seed shell. This difficulty may not be met with when shelled stones are sown. If the growing tip succeeds in extricating itself at an early stage, the stem distortion is slight and such stems may gradually become straight later on (Plate XXXVIII, fig. 1). Where the emergence is delayed the seedling stems may continue to be crooked so as to render them unfit for inarching. While maintenance of a good soil tilth may certainly minimize the number of seedlings with defective stems, the method of treatment of seeds and of sowing, which are believed to be the chief contributory factors, require also to be attended to.

To throw more light on the above questions, 765 mango stones were sown in 1937 by 10 different methods. Of these, 405 stones were shelled and the remaining 360 were sown unshelled. Each of these two lots was sown by five different methods in almost equal numbers as under :—

(*a*) stones sown with plumule pointing upwards ;
(*b*) stones sown flat on the sides ;
(*c*) stones sown with suture upwards ;
(*d*) stones sown with suture downwards ;
(*e*) stones sown with plumule pointing downwards.

All these methods are illustrated in Plate XXXVIII, fig. 1 in so far as unshelled stones are concerned. In Plate XXXVIII, fig. 2, a typical seedling obtained from the shelled stone sown with plumule up is also shown alongside the seedling from unshelled stone sown by the same method. A close examination of the root and stem portions of the typical specimens shown in these figures as well as the observations made on all the seedlings show that :—

(*a*) sowing the mango stones with plumule up produces a straight tap-root and stem, both of which characters facilitate inarching and root-grafting operations ;

(*b*) sowing the stones by any of the other four methods tested, induces a crooked formation of the tap-root and stem of the resulting seed lings, the degree of crookedness occurring roughly in the following descending order of magnitude in these four methods : (1) stones flat, (2) stones with suture up, (3) stones with suture down, and (4) stones with plumule down and

(*c*) shelled stones produce a straighter tap-root and stem than unshelled stones, but the germination percentage in the former group has been found to be very much lower than in the latter.

For convenience of root-grafting and inarching operations as also for all other methods of vegetative propagation, sowing of unshelled stones with plumule up offers, therefore, greater advantages than the prevalent method of sowing the unshelled stones flat.

The practice of shelling the stones before sowing would seem to be preferable from these data to the sowing of unshelled stones in so far as the production of straight-stemmed seedlings are concerned, and also for an effective elimination of diseased or worm-infested kernels. The shelled stones also were found to germinate on an average 12 days earlier than unshelled stones in the above experiment. But the germination in the former was less by about 14 per cent than the latter. In view of the expensiveness of shelling operation and the cheapness of mango stones, it s therefore doubtful if Indian nursery trade will resort to shelling on a commiercial scale, despite certain advantages associated with it.

B. Grading of stones in relation to germination percentage

During the 1936 mango season, 6,713 fruits were collected from seven seedling trees, and the fruits were graded into three different groups according to size. The stones extracted from each of these three grades were again graded according to the size of stones into three sub-groups. The germination percentage of each of these are set forth in Table II.

It is apparent from these figures that large-sized fruits have not invariably given a higher percentage of germination in all the progenies. As regards the effect of grading stones on germination, the differences between the various groups are also contradictory, although small stones from smallest-sized fruits have generally accounted for the lowest germination percentage. The diflerence between the grades is not in any way larger than that noticed between seed parents ; for instance between 5/1 ad 0/6. It is, therefore, doudtful if grading of fruits or stones can be classedns a necessary operation in mango nursery practice in view of the contradictory results or the small differences between the various groups or sub-groups.

C, Vigour and measure of variability in mango seedlings

Height and girth records of each of the 3,819 seedlings raised under the preceding experiment were collected on two different occasions, once during the second week of August 1936, and again during the second week of the following November. The coefficient of variability was calculated on the basis of these measurements. The concerned data relating to the stem diameter measurments collected during the second week of November 1940 are only presented in Tables III and IV.

The inferences drawn from these, however, appear to hold good in the case of the data collected on previous occasion also, both in respect of height and stem diameter measurements.

It is observed from these data that the vigour of seedlings from different parents differs to a certain extent. Tree No. 5/1, for instance, has produced in general a larger-sized batch of seedlings than tree Nos. 83 and 5/6.

The coefficient of variability ranges from 12·30 to 39·81 in respect of height measurements and from 14·79 to 64·57 in terms of stem thickness.

It appears that vigour of seedlings is not influenced to any appreciable extent by the size of fruit or stone in the case of progenies raised from seedling mango trees. It is, however, possible that the inherent vigour of the seed parent is a dominating factor masking all possible influences, as those of fruit or stone size, on the vigour of seedlings.

During the 1938 season, about 27,000 stones from 29 different seedling trees were sown in separate beds for raising seedling rootstocks. This large collection of seedlings exhibited, at a very early stage of their growth, pronounced differences between the progenies in the matter of size. In order to gather information on the extent of differences in seedling size between the various progenies, height and girth measurements of the individual seedlings of 11 different progenies sown in June 1938 were collected in April 1939. The analyses of these measurements showed that the mean height ranged from 29·93 cm. to 62·80 cm. and the mean girth from 0·50 cm. to 1·08 cm. Tree No. 0/4 produced within a period of about nine months from sowing the largest-sized seedlings suitable for use as rootstock for inarching or budding operations. This, in effect, means a saving of considerable time and expenditure to the nurserymen during the pre-inarching period, if the progeny of this tree is preferred to others as rootstocks and if this progeny continues to maintain its superiority over others in future also.

D. Transplantation and watering of seedlings

It is the universal practice in this country to retain a ball of earth around the roots of mango seedlings at the time of their transplantation. It has been previously pointed out that during the examination of the root of some polyembryonic mango seedlings in 1937, it was found feasible to transplant some seedlings with naked roots also. To confirm these observations a separate trial was initiated in the same year. It was found from this trial that, out of 129 seedlings of about 6 months' of age transplanted with naked roots on 11 January 1937, 82·9 per cent survived, as against 86·9 per cent success obtained by transplanting seedlings of the same age and on the same date with a ball of earth having an average diameter of 6 in. at the collar. In both the batches, the roots were shortened to nine inches from the ground-level and the seedlings were transplanted into nursery beds under the shade of an old mango tope. It is apparent, therefore, that the exposure of roots for a short duration at the time of transplanting is not detrimental to the life of the mango seedlings, under conditions existing at this station and in the seasons in which the trials were carried out.

It will be shown later under root-grafting trials that the above inferences are amply corroborated by the data collected in some other independent trials also.

TABLE

Germination percentage of mango stones of 7 seed parents graded

(Seeds sown from May to July

Tree No.	Big fruits						Medium fruits			
	Big stones		Medium stones		Small stones		Big stones		Medium stones	
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
5/1	57	87·7	95	81·1	67	79·1	66	84·8	87	65·5
83	70	75·7	100	65·0	164	50·0	129	76·7	160	68·1
0/2 . . .	230	69·1	170	67·6	94	46·8	238	63·0	240	62·9
2/3	163	55·2	90	55·6	40	40·0	36	55·6	40	42·5
1/2	123	61·0	110	50·9	66	47·0	152	52·6	114	8·51
0/6 . . .	215	45·1	114	35·1	33	45·5	154	62·9	175	29·8
5/6 . . .	55	65·4	75	77·3	32	68·8	88	47·3	114	55·1

II

according to size of fruits and stones prior to sowing

1936 soon after extraction)

Small stones		Small fruits						Average weight of fruits (oz.)	Average weight of stones (oz.)
		Big stones		Medium stones		Small stones			
No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent		
83	61·4	71	81·7	66	48·5	64	67·2	Big . . 4·31 Medium . 3·12 Small . 3·02	Big . . 0·85 Medium . 0·78 Small . 0·71
148	56·1	77	57·1	100	51·0	96	32·3	Big . . 3·05 Medium . 2·86 Small . 2·42	Big . . 0·62 Medium . 0·57 Small . 0·57
191	50·8	45	64·4	73	61·4	84	26·2	Big . . 3·89 Medium . 3·16 Small . 3·01	Big . . 0·86 Medium . 0·83 Small . 0·74
30	43·3	55	52·7	62	43·5	60	41·7	Big . . 3·52 Medium . 3·05 Small . 2·88	Big . . 0·63 Medium . 0·59 Small . 0·57
84	51·2	90	38·9	91	·6	167	43·1	Big . . 3·76 Medium . 3·51 Small . 3·12	Big . . 0·62 Medium . 0·57 Small . 0·48
82	28·1	128	37·5	249	12·9	262	10·4	Big . . 4·62 Medium . 3·97 Small . 3·92	Big . . 0·74 Medium . 0·69 Small . 0·63
96	75·0	72	48·9	113	50·1	144	42·2	Big . . 3·44 Medium . 3·22 Small . 3·01	Big . . 0·59 Medium . 0·54 Small . 0·50

TABLE

Average height of mango seedlings

Tree No.	Big fruits						Medium		
	Big stones		Medium stones		Small stones		Big stones		Medium
	Height cm.	C*	Height cm.	C	Height cm.	C	Height cm.	C	Height cm.
5/1	34·49	31·62	34·30	22·91	41·02	25·12	36·42	19·50	45·16
83	25·90	26·30	23·33	27·54	19·48	30·20	24·18	26·92	21·89
0/2	24·36	25·12	26·03	24·55	35·55	38·90	20·61	25·70	18·90
2/3	26·42	21·38	26·98	17·78	27·26	12·30	29·49	16·60	29·24
1/2	26·46	27·54	29·37	25·12	23·12	27·54	24·58	28·18	23·14
0/6	25·42	24·55	24·41	27·54	20·92	36·31	24·18	28·84	22·24
5/6	21·32	30·90	17·97	25·12	17·58	30·90	20·25	28·84	19·45

TABLE

Average diameter of mango seedlings at 3 cm.

Tree No.	Big fruits						Medium		
	Big stones		Medium stones		Small stones		Big stones		Medium
	Diameter cm.	C*	Diameter cm.	C	Diameter cm.	C	Diameter cm.	C	Diameter cm.
5/1	0·66	27·54	0·58	26·30	0·58	33·88	0·44	64·57	0·60
88	0·51	23·99	0·45	25·70	0·39	26·92	0·46	21·88	0·43
0/2	0·44	32·36	0·47	25·70	0·40	27·54	0·38	28·84	0·40
2/3	0·38	42·66	0·47	20·42	0·48	14·79	0·50	18·20	0·46
1/2	0·45	24·55	0·53	22·91	0·43	22·91	0·45	54·95	0·42
0/6	0·51	17·38	0·47	26·30	0·47	15·14	0·38	52·48	0·45
5/6	0·40	22·39	0·37	22·91	0·38	16·22	0·39	22·91	0·37

C—Coefficient of variability

III

and their measure of variability

fruits			Small fruits					
stones	Small stones		Big stones		Medium stones		Small stones	
C	Height cm.	C	Height cm.	C	Height cm.	C	Height cm.	C
21·38	37·17	26·30	32·38	25·12	28·66	30·90	33·45	26·92
30·20	24·19	39·81	19·96	26·92	21·18	29·51	18·26	31·62
28·18	19·63	28·84	19·22	28·84	18·91	29·51	16·35	26·92
14·79	25·39	15·49	27·58	19·95	26·45	18·20	26·15	25·12
23·99	21·87	24·55	22·99	23·44	25·63	21·38	23 05	28·18
20·89	23·27	19·05	21·40	22·39	22·68	28·18	17·11	26·92
25·70	17·98	25·70	18·28	20·89	15·66	39·81	17·43	26·30

IV

above ground-level and their measure of variability

fruits			Small fruits					
stones	Small stones		Big stones		Medium stones		Small stones	
C	Dia-meter cm.	C	Dia-meter cm.	C	Dia-meter cm.	C	Dia-meter cm.	C
29·51	0·63	19·95	0·54	25·70	0·51	23 44	0·61	25·12
28·18	0·37	29·51	0·38	25·12	0·37	27·54	0·41	25·70
27·54	0·35	33·88	0·36	25·12	0·34	29·51	0·26	18·20
16·98	0·40	17·78	0·46	23·99	0·41	23·44	0·43	23·99
23·99	0.39	16·22	0·44	30·20	0·49	19·50	0·43	28·18
21·38	0·47	16·60	0·42	20·42	0·38	26·30	0·31	33·88
20·89	0·34	38·90	0·35	26·92	0·33	25·70	0·72	58·88

Subsequently, in 1939-40 a series of trials were carried out with a varying number of seedlings to test the efficacy of lifting seedlings and potting them after partial defoliation. It was found from these trials that lifting mango seedlings for potting seven to nine days after heavy defoliation, when only a couple of leaves in the terminal rosette are retained, reduces the mortality of such seedlings to the minimum extent possible even during hot and dry periods of the year.

From a different series of rough trials it was also found that, as against the common practice in South India of watering the potted mango seedlings daily, the irrigation interval can be extended to three to five days, depending upon the weather conditions, if the potted seedlings are kept close together in a trench and water is let in in a manner to fill the trench up to the edge of the pots. The latter practice is said to be fairly well known in parts of Bombay province and deserves to be adopted in other parts of the country as well.

Inarching

A. Age of rootstock seedlings for inarching

During 1935-36, 1,056 seedlings of different ages were used for inarching, mainly to raise the requisite number of grafts for planting in the variety collection plot. From these it became clear that inarching of young seedlings of even 4½ months of age could be done successfully. A take of 62·5 per cent was obtained in one lot of 192 seedlings of 4½ months of age inarched in February 1936. Paul and Guneratnam [1937] have stated that stocks between six months and one year old give more vigorous and earlier-bearing plants when grafted or budded. It was not possible to study at Kodur the orchard performance of grafts on very young rootstocks. Till this is done, it will not be possible to recommend their use in commercial mango culture.

However, with the available facilities a small trial was initiated during February 1937 to ascertain the effect of seedling rootstocks with ages ranging from 7½ to 16½ months at the time of inarching. A total number of 1,365 stones from a single seedling tree were sown on 17 June 1936, for the purpose of this trial, after grading the stones according to three different sizes. Of the seedlings obtained from the largest-sized stones, 100 seedlings which were apparently most uniform in growth and vigour were selected for the purpose of this trial and these were potted on 6 January 1937. These seedlings were inarched to selected scion shoots from a single Neelum tree in batches of 25 each on four different occasions at intervals of three months each, by a single operator. The grafts in every case were separated exactly four months after the date of inarching. The girth measurements of the rootstocks at the time of potting as well as on 27 March 1938 were collected and recorded. Similar records were intended to be collected once a year after planting of the finally selected grafts in the orchard site.

Table V summarizes the records collected prior to the final planting of the trees.

The data in the table do not render it possible to draw any definite inferences. However, the increased girth measurements recorded in the earlier inarched batches is a point worth mentioning.

TABLE V

Records of Neelum grafts on rootstocks of different ages

Rootstock parent—Country 0/2, F. R. S.; Scion parent—Neelum (57 C. R. Garden)

Serial No.	Age of the rootstock at the time of grafting	Date of inarching (1937)	Date of separation (1937)	Percentage take	Mean girth of the stock at 1 in. below the union on 27 March 1937 in cm.	Mean girth of the scion at 1 in. above the union on 27 March 1937 in cm.
1	7½ months . . .	2 Feb. .	2 June .	96	4·05	3·52
2	10½ months . . .	2 May .	1 Sept. .	92	3·45	2·6
3	13½ months . . .	2 Aug. .	2 Dec. .	92	2·86	2·23
4	16½months . . .	2 Nov. .	2 Mar. .	92	2·98	2·33

The selected grafts were planted out on 31 December 1939 in a separate plot according to the lay-out approved by the Statistician to the Imperial Council of Agricultural Research, New Delhi. The details of the material used other than those already furnished above and the method of lay-out are shown below :—

Plot size	40 ft. × 120 ft. (0·11 acre)
Number of plants in each plot . . .	3
Spacing	40 ft. square
Number of replications	4
Performances of the scion parent . .	1936—50 to 100 fruits 1937—25 to 50 fruits 1938—Over 100 fruits
Treatments	A—Neelum on rootstocks of 10½ months of age while planting B—Neelum on rootstocks of 13½ months of age while planting C—Neelum on rootstocks of 16½ months of age while planting

The girth and height measurements of each of the 36 Neelum grafts, as collected at the time of planting, when analysed, have shown that there is no significant difference between the three batches of grafts either in regard to the height or girth measurements. This seems to falsify the popular belief that older the rootstocks the greater the size of the grafts in the plantation.

Similar measurements were collected on 8 June 1940, i.e. 18 months after planting. These data also when analysed statistically have failed to show any significant differences between the three treatments. Selection of Neelum grafts on older rootstocks would therefore appear to be not an advantageous practice at least within the age limits included under this trial and from the point of view of growth performance of the trees within the first 18 months of planting.

B. Season for inarching

In order to gather an idea regarding the optimum period for inarching of the most important commercial varieties of mangoes in this tract, an experiment was planned out in the beginning of 1936. Two Neelum trees and two trees of Bangalora were selected every month as scion parents for this purpose in a neighbouring plantation. All these had reached their full

bearing age, having been planted about 20 years prior to the commencement of this trial.

Every month 100 grafts were prepared at the rate of 25 on each tree or 50 in each variety. Two months after this operation, the first cut was given to the seedling rootstock and the scion followed by the second cut after three months, and the final separation of the grafts was effected four months after the date of inarching. The grafting was done by two independent operators, one tree of each variety having been allotted to one operator every month. The age of the seedling rootstocks used in different months differed to a certain extent, as it is bound to be in a crop wherein fresh seeds become available for sowing only in a short period of the year. In spite of the aforesaid unavoidable vitiating factors, the results obtained are considered to be of sufficient practical importance.

The analysis of variance worked out for the results of all the 12 months is presented in Table VI.

TABLE VI

Analysis of variance

Serial No.	Due to	Degrees of freedom	Sum of squares of deviations	Mean square	Significance
1	Varieties . . .	1	1065·97	1065·97	$P< 0·05$, significant
2	Months . . .	11	14115·71	1283·25	$P< 0·01$, very significant
3	Operators . . .	1	231·54	231·54	$P> 0·05$, not significant
4	Interaction of varieties to months	11	1090·04	99·09	Not significant
5	Interaction of varieties to operator	1	13·13	13·13	Not significant
6	Interaction of operator to months	11	1583·67	143·97	Not significant
7	Error . . .	11	1266·88	115·17	Not significant
	Total .	47	19366·94	412·06	

S. E. of differences between means for varieties= 3·10

S. E. of differences between means for operators= 3·10

S. E. of differences between means for months= 7·89

Critical difference for varieties= 6·82

Critical difference for months= 22·57

The mean percentage take for each month and for each variety is presented in Table VII.

Table VII

Mean percentage take in each month and for each variety

Varieties	Percentage take in each month (1936-37)												General mean per cent
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	
Neelum .	88	69	52	100	100	94	64	94	98	98	96	98	87·6
Bangalora .	78	74	20	88	96	96	64	76	88	82	86	90	78·2
Average .	83	72	36	94	98	95	64	85	93	90	91	94	...

The efficiency of take during the several months is arranged in descending order as follows :—

Aug. Sept. July March Dec. Feb. Jan. Nov. April May Oct. June

(The treatments under or above the same bar do not significantly differ from each other.)

The greatest efficiency is got in the months of August, September, July, March, December, February and January followed by November and April. May and October are next in order, while June is the worst month. It is seen that, on the whole, Neelum contributes to a greater success by the process of inarching than Bangalora, and the difference between the two varieties, namely 9·4 per cent, is statistically significant. It is also evident that there has been no significant difference between the operators.

The take recorded in the above experiment does not wholly tally with that obtained in a separate trial during 1937 with Neelum scion (Table V). In the latter case, inarching in February has contributed the maximum take, while no difference is noticed between the take recorded in May, August and November. On the other hand, in the former trial, although the take in Neelum plants inarched in February is identical with that obtained in the latter trial and the take in plants inarched in November 1936 and 1937 are nearly so, a slightly higher figure is noted in plants inarched in August 1936, and a very much smaller figure in plants inarched in May 1936 than in those inarched in the corresponding months in 1937. These differences are easily accounted for by the variation in weather conditions from year to year and also in the age of the seedling rootstocks.

C. Separation of grafts

Ordinarily all grafts are separated out by the nurserymen from the scion parents about three months after the inarching operation in this tract. But a noticeably large number of casualties occurred during 1937 and 1939 in Rumani variety soon after separation of the grafts after the above period, although no such ill-effects were observed in the case of Neelum and Bangalora grafts. Consequently during 1939-40, the separation of grafts of Rumani from the scion parent was delayed by a month with obvious benefit. It

seems clear from these observations that different varieties demand different lengths of time from inarching to separation stage, and in case of Rumanis at least a four-month period is essential, even though an equally high success can be got in Neelum and Bangalora with a three-month period.

D. Treatment of grafts after separation

A preliminary trial to test the efficacy of the prevalent practice of nursing the grafts for some time immediately after separation from scion parent was carried out on three different occasions during 1939-40, using 24 grafts four at each time. The results show that the grafts can be depotted and planted successfully in their permanent orchard sites, immediately after separation from the scion parent and after four months from the date of inarching, during November-February. Such treatments as those referred to in the preceding sentence were responsible for an earlier manifestation of 'flush' than in the case of grafts kept in pots under shade for nursing after separation. The difference in the time taken to flush between the batches of grafts planted soon after separation and those kept under shade was 87 days in the case of grafts separated in the beginning of November, while in the grafts separated out and planted at the end of December and end of January, the number of days taken to flush were 77 and 69 respectively, as against no flush in the comparable batches of grafts kept under shade until the end of the year under report.

It is known that there is a wide dissimilarity in the fruit nursery trade in India in regard to the period of nursing the grafts after separation. While several nurserymen in South India often sell grafts almost immediately after separation, in other parts of the country it is believed that the grafts should be nursed at least for four months after separation. The above-stated results, relating as they do to a few grafts prepared and nursed with special care, may not therefore provide a safe guide for widespread application.

Root-grafting

Since no commercially successful method of vegetative reproduction of mango rootstocks has yet been devised, some means of obtaining uniform material with a miscellaneous seedling basis is found necessary to render accurate field trials on mangoes possible. It has already been pointed out by other workers that a stem-piece of the rootstock often masks and outweighs the influence of the absorbing root-system and, therefore, if only the root-piece of the seedling rootstock is grafted to the scion thus eliminating the stem influence of the rootstock, it should be possible to obtain a uniform material for the purpose of field trials. The success of the method will depend upon the ability of the mango seedlings to withstand exposure of root during the root-grafting operation, the ease with which the root-piece can be grafted to the scion, and perhaps also the season of operation and the age of rootstock and scion.

With a view to elucidating these various problems, a number of preliminary trials were laid out during 1936. One of these was intended to ascertain the most suitable method of making the maximum number of potted seeding rootstocks available with about three inches of root-piece exposed for the root-grafting operations.

The following three methods were tested in this connection :—

(*a*) Lifting seedlings direct from open nursery beds and transplanting them into beds under shade and again re-lifting these with naked roots and potting them with about 3 in. of root-piece exposed.

(*b*) Lifting seedlings from the nursery beds with naked roots and potting them, and again transferring them after a period to fresh pots with about 3 in. of root piece exposed near the collar.

(*c*) Lifting seedlings direct from open nursery beds and potting them with about 3 in. of root-piece exposed near the collar.

The plants used in the experiment were those the seeds of which were sown in April 1936. The primary lifting in (*a*) was done in January 1937 and in (*b*) in December 1936. While potting the seedlings finally, care was taken to keep the seedling close to the edge of the pot to facilitate the grafting operation. A further device which subsequently proved very useful was also adopted, and this consisted of making a U-shaped notch, 1 in. wide and 2 in. long, close to the edge of the pot. The exposed root-piece of 3 in. long was made to project out through this notch.

The final potting was done every month commencing from May 1937 in the case of method (*b*). In the case of (*a*), the final potting was done every month from May to December 1937. In method (*c*), the final potting was done only twice, viz. May and July 1937 and was not repeated subsequently as none of the plants survived the treatment.

In every trial, the number of seedlings selected for the final potting operation in these preliminary trials was 12, and the same operator was responsible for the lifting and potting operation in all the three methods.

The percentage of survivals in method (*a*) was roughly 50 in May, 16·7 in July, 25 in October and nil in other months, while in method (*b*), it was about 75 in May, September and October, between 50 and 75 in July, November, December and January, between 25 and 50 in June and February and less than 25 in August. Method (*c*), as has already been stated, failed to produce any success.

The above figures show that method (*b*) has invariably proved the most suitable and, further, that September, October and May were the three optimum months during 1937-38 for this treatment. It is of considerable interest to note that, contrary to the existing belief that mangoes do not transplant well without a ball of earth around the root, over 50 per cent survivals were obtained by method (*b*) on seven months and about 75 per cent in three out of ten months for which the results are available.

Side by side with the above trials, preliminary investigations were initiated to find out the most suitable method and season for the root-grafting operations. At the outset, it was found that root-grafting of the seedlings, immediately after they were lifted from the open beds with naked roots and potted, failed to give much success as only two out of eight in May 1937 and none out of the same number in July 1937 showed successful takes.

Among those lifted and potted as per method (*b*) described above and root-grafted immediately after final potting in 1937, the number of successful takes obtained out of eight in each month have been five in those grafted in May, two in June, none in July, three in August, none in September, one in October and three in November.

In the case of seedlings lifted and potted by method (*a*) and root-grafted immediately after final potting, the number of successful takes obtained out of eight grafted every month in 1937 have been nil in those worked in May, two in June, three in July, four in August, nil in September, one in October and nil in November.

On the other hand, among the seedlings which were finally potted after various treatments and root-grafted after about a month's hardening, the percentage take has been 40 in those grafted in May, 60 in June, 22 in July, 100 in August, 30 in September, 38 in October, 17 in December, 50 in January and 33 in February.

Since the number of plants root-grafted in the various months is small, it will be idle to draw any valid inferences from the above figures. It is, however, possible to state from these preliminary trials that root-grafting is an operation which is feasible in mangoes (Plate XXXIX, figs. 1-3). The figures also indicate the possibility of raising a sufficiently large number of mango root-grafts with ease for the purpose of initiating accurate field trials. Further trials are no doubt called for to ascertain the optimum season for root-grafting operation, and these were undertaken on an elaborate scale during the following year. The question of the best method of planting root-grafts in the orchard site without any damage to the tender parts of the graft-joint by irrigation required also to be investigated, and this was also attended to during 1937 and 1938. None of the 15 root-grafts planted in these two years showed the least sign of damage to the graft-joint after a year of planting. This preliminary observation was considered sufficient for the time being to enable the raising of a larger plantation of root-grafts for further field tests.

Accordingly, 900 mango seedlings from one mono-embryonic seed parent were lifted with naked roots and potted in November 1938, four months after sowing in seed-beds. Of these, only 44 or about 5 per cent died soon after potting, while 81 seedlings suffered to a varying extent as a result of these operations. The low mortality, or in other words, the high percentage of survivals in these seedlings again confirms the previously recorded results, that mango seedlings can be lifted successfully with naked roots in commercial nursery practice.

During February 1939, 610 good seedlings were selected from the above-mentioned batch of potted seedlings and were re-potted for root-grafting purposes into U-notched pots, exposing 2-2½ inches of tap-root near the collar. A very much larger number of casualties occurred in this re-potting operation than during the first potting period. The seedlings that finally survived were root-grafted to two selected trees of Neelum and one of Bangalora in July 1939. The details of the success obtained are set forth in Table VIII.

The above operations were carried out along with some inarching, double-working, cleft-grafting, side-grafting and budding trials under similar and uniform conditions. But the data relating to other methods are not presented here. However, it is observed from the data in Table VIII that root-grafting operation performed in July 1939 has been responsible for a very high take. If allowance is made for the large mortality of seedlings during the re-potting operation, it would, however, be found that this propagational method compares very unfavourably with inarching. In order to present a comparative idea of the actual number of plants finally obtained from every

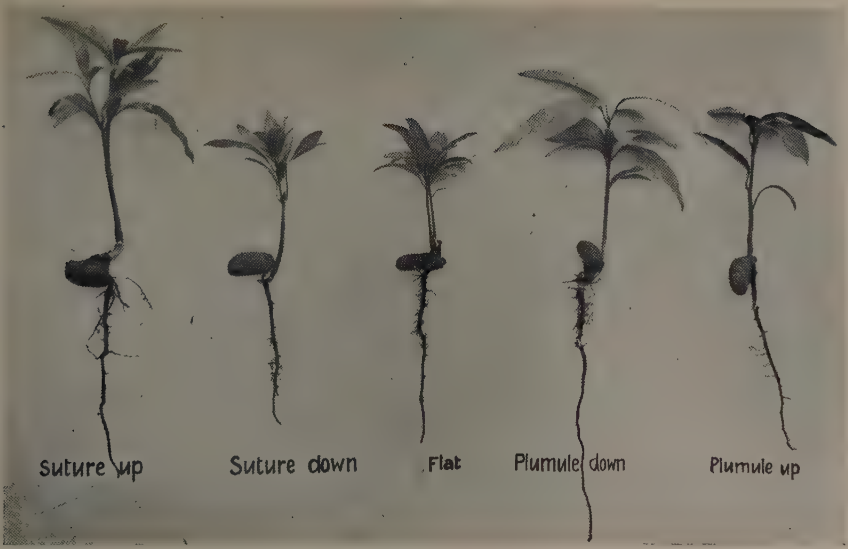


FIG. 1. Var. Country, unshelled stones : D. S.=31.7.37 ; D. Ex.=15.12.37

FIG. 2. Var. Country : D. S.=31.7.37 : D. Ex. 15.12.37

FIG. 1. Mango seedling soon after lifting, with naked roots

FIG. 2. The same potted with about $2\frac{1}{2}$ in. of root near the collar protruding out of U—notch

FIG. 3. A root graft ready for planting out

FIG. 4. Mango cutting : S=3.7.36 ; R=23.7.37 ; P=22.9.37 ; Sp=16.10.37 ; Ex.=26.11.37

100 seedlings originally selected in seed-beds for the purpose of the various propagational methods included under one comparative trial, the following figures are presented.

TABLE VIII

Details of success from mango root-grafting trials, 1938-39
(Seed parent—7/1 F. R. S.)

Serial No.	Propagation method and scion parent	Number grafted	Date of grafting (1939)	Date of separation (1939)	Percentage take
1	Root-grafting—Neelum 1st scion parent	72	11 July .	31 October	97·22
2	Root-grafting—Neelum 2nd scion parent	16	14 July .	Do. .	93·75
3	Root-grafting—Bangalora 1st scion parent	88	8 July .	Do. .	95·45

Propagational method and scion variety	Percentage of grafts obtained from the orginally selected seedlings
Root-grafts of Neelum	23·81
Root-grafts of Bangalora	23·39
Double-grafts of Neelum	54·11
Double-grafts of Bangalora	71·94
Inarched plants of Neelum	84·42
Inarched plants of Bangalora	90·00
Shield-budded plants of Neelum	71·06
Patch-budded plants of Neelum	67·57
Shield-budded plants of Bangalora	21·84
Patch-budded plants of Bangalora . . .	8·58
Cleft-grafted plants of Neelum	0·85
Cleft-grafted plants of Bangalora . . .	0·85

Despite its low efficiency in comparison with inarching, double-working and budding with one scion variety, it is obvious that root-grafting is a feasible nursery practice in an ever-green tropical fruit like mango.

BUDDING

A rough preliminary trial on the budding of mangoes was first initiated at Fruit Research Station, Kodur, in June 1937. Six different methods of budding were tried with 48 seedlings of about 12 months of age growing in open nursery beds. The methods followed are briefly described below :—

Method 1 : A transverse incision was made in the bark of the seedling rootstock as far as the cambium and the bark was then peeled down up to a length of about 1½ in. after making two vertical parallel cuts connecting the two ends of the transverse cut. The peeling has to be done carefully so that it may come out in one strip. The bud-shield was removed in the same manner as in oranges with a small piece of wood

attached to it, and this was pushed under the flap till all the exposed edges of stock rind and bud-shield were in perfect contact. In order to do this, the size of the bud-stick is required to be the same as that of the stock stem. The flap was brought into position and made to cover the bud-shield completely. The covered bud was then wrapped around with paraffined cloth and finally by a piece of dried banana sheaths. This method is almost similar to that described by Paul and Guneratnam [1937].

Method 2 : This method is identical with the chip budding described by Fielden and Garner [1936], except that no sealing of the cut surface was done in these trials. The buds were wrapped around with paraffined cloth strips.

Method 3 : This is exactly the method of 'invert-T' budding or the shield method employed for budding citrus plants. The bud was inserted with a piece of wood attached o the bud-shield.

Method 4 : This method resembles the modified Forkert method described by Fielden and Garner [1936]. The bud-shield inserted in this method also had a piece of wood attached to it and paraffined cloth was also wrapped around the bud.

Method 5 : This resembles the patch budding described by Fielden and Garner [1936]. The width of the bud-shield was about an inch. The bud was wrapped round the stock after insertion with raffia fibre, and over this by paraffined cloth.

Method 6 : This method is practically similar to method No. 5 and is designated as modified patch-budding or flute-budding by Fielden and Garner [1936]. The wrapping of the bud after insertion was done in a similar manner as described in the preceding method.

In all these cases, the paraffined cloth, raffia or banana sheath coverings were removed three to four weeks after bud-insertion. The flaps of bark were also cut off wherever they had been retained if the buds were found green at this time, and the rootstock seedling was ringed about an inch wide and about two inches above the point of insertion in order to stimulate the growth of bud-sprouts. After the bud-sprouts had sufficiently matured, as was indicated by the dark green colour of leaves, the rootstocks were lopped off above the point of bud-insertion.

A month after insertion, it was observed that 37 buds out of 48 were green and alive, of which the largest number was in the batch budded by method No. 1 and least in the plants worked by method No. 3. Analyses of the finally available bud-sprouts after 3 months of insertion, however, showed that method No. 2 did not produce a single take, methods Nos. 3-6 were responsible for a take of only one or two in each, while method No. 1 produced the highest successful take of five out of eight insertions.

In a separate trial, 24 'petioled' and 24 'unpetioled' buds of one scion variety were inserted by these six methods in July 1937. The 'petioled' buds are those which are inserted with a portion of the petiole attached to the bud-shield. In the case of 'unpetioled' buds, however, the leaves of the selected bud sticks are completely removed, wherever they are found, about a fortnight before the actual insertion. The petiole is absent in the bud-shield and the scar caused by the defoliation is healed by the time of insertion, and in some instances the dormant bud is also slightly stimulated into activity. The number of successful budded plants out of these 48 insertions amounted to 21, petioled buds accounting for 11 of these successful takes, and method Nos. 2 and 5 showing the lowest takes of one each.

In addition to these trials which were carried out in open nursery beds, 24 seedlings in pots were budded in June and July 1937 by the above-mentioned six methods. Unlike in the open beds, the success obtained in these potted seedlings has been very poor, only two plants in June and one in July

1937 having shown a successful take. It is possible that the relatively slow growth of rootstocks in pots hinders the successful take of mango buds.

The only possible inference that could be drawn from these small preliminary trials was that in the open beds budding of mangoes offers a good chance of becoming an established nursery practice.

Owing to the unexpected death of trained mango budder, it was not possible to undertake a comprehensive trial on budding of mangoes during the following year. However, a number of persons were given training in various methods of budding, and a total number of 643 buds were inserted at different times of that year. In the October (1937) insertions, one of the budders under training was able to obtain 50 per cent take, which is considered to be a fairly good index of the skill of the operator as well as a good indication of the possibility of budding in commercial nursery practice.

During 1939-40, a series of budding trials were again conducted, once along with some side-grafting trials, and again along with a number of other propagational methods. In the former case, it was intended to compare side-grafting, using terminal scion shoots, with patch-budding in respect of two scion varieties, viz. Alfonso and Erramulgoa. The lay-out of this trial consisted of four replications for each of the four treatments with 18 seedlings per plot or 72 per treatment. The treatments were randomized within the blocks. A single operator was employed in this trial also. The operations were done from 22 to 25 August 1939, when the days were very windy, dry and warm. The summary of the results is presented in Table IX.

TABLE IX

Mango side-grafting and patch-budding trials showing the summary of result regarding the take of scions

	Erramulgoa patch budding (A)	Alfonso side-grafting (B)	Erramulgoa side-grafting (C)	Alfonso patch budding (D)	General mean	S. E. D. mean	Level of significance	Critical difference
Mean take per treatment (per cent)	61·11	48·61	38·39	16·67	41·32	12·33	$P=0·05$ $P=0·01$	27·64 39·75
Mean take as per cent of general mean	147·89	117·64	94·12	40·34	100·00	29·60	$P=0·05$ $P=0·01$	66·89 96·20

Conclusions: Erramulgoa patch-budding — Alfonso side-grafting — Erramulgoa side-grafting — Alfonso patch-budding

(Treatments under or above the same bar do not differ significantly from each other)

The very large difference noticed between the two varieties in Table IX in regard to the take of buds strongly indicates that different mango varieties respond differently to this method of mango propagation.

In the second comparative trial conducted in 1939-40, shield (method No. 3) and patch method (method No. 1) of budding were only employed. Neelum and Bangalora were selected as scion parents and tree No. 7/1 from the Station tope was used as second parent. The seeds were sown on 26 June 1938, and the seedlings were transplanted into fresh nursery beds on 25 February 1939. The germination percentage recorded in these was 50 and the percentage of success in transplantation 85. The success obtained is shown in Table X.

TABLE X

Success from budding of mango in 1939

Serial No.	Method of budding	Scion variety	Date of budding	Number budded	Percentage take
1	Shield . . .	Neelum .	4 July 1939	73	83·56
2	Patch . . .	Do. .	7 July 1939	73	79·45
3	Shield . . .	Bangalora	8 July 1939	140	25·70
4	Do. . . .	Do. .	Sept. 1939	21	23·80
5	Patch . . .	Do. .	Do. .	24	8·30
6	Shield . . .	Do. .	Oct. 1939 .	30	13·30
7	Do. . . .	Do. .	March 1940	25	20·00

The wide differences between the takes of buds of Neelum and Bangalor strongly confirm the previous recorded inference that certain mango varietie respond better to this method of propagation than others. From invest gations conducted thus far with four different varieties, it is clear that Neelur and Erramulgoa have proved at this Station to be most suitable for propa gation by budding during July-August, while Bangalora and Alfonso hav proved relatively unsuitable.

Between shield and patch methods of budding as tried during the yea under review, the former has contributed a slightly higher success than th latter, but the difference is too small to vest the former method with an great importance.

SIDE-GRAFTING

At the suggestion of the Agricultural Commissioner with the Goverr ment of India, trials on side-grafting of mangoes as advocated by Nakamur [Tanaka, 1939] were undertaken during 1939. At the outset, 27 seedling were utilized in July 1939 by one budder for gaining suffi cient practice wit this operation. An unexpectedly high take amounting to 92·59 per cer obtained in this lot indicated the necessity for carrying out more compre hensive trials with this method of propagation.

In one series of trials laid out subsequently, 26 Neelum and 26 Banga lora soft-wood scions from the apical region of the shoot were selected durin an intermittent rest period between two cyclic growths and these were pr cured according to the method suggested by Nakamura [Tanaka, 1939] be fore side-grafting them to 52 one-year-old seedlings on 4 and 5 Augus 1939 by one single operator.

The percentage take in these batches was found to be 92·31 in Neelur and 88·46 in Bangalora, of which 76·93 per cent of the scions in the forme and 53·85 per cent in the latter variety had sprouted and were in activ

growth within 26 days after the operation. Closer examination of the materials used for this trial revealed that all the failures were restricted to those scions which had a diameter of less than 0·5 cm. each. It was also found that scions that are likely to fail, shrivel within a week after the operation, and those that are likely to take will have a number of ant visitors. The latter observation is in conformity with those recorded by Tanaka [1939]. It was also noticed that several well-developed scions started into active growth within about 10 days after the operation in this month, while Nakamura [Tanaka, 1939] noticed such a phenomenon only 22 days after insertion.

The comparative trial with side-grafting and budding has already been reported (Table IX) under the preceding subject of budding.

In a small but independent trial, 72 scions of Alfonso from the mid-portions of the shoots and a similar number of shield-buds of the same variety were inserted during September 1939 in nursery beds, and these have registered a take of 23·6 per cent and 27·8 per cent respectively. The inferior value of mid-portions of scion shoots is therefore indicated.

It has been previously shown that terminal scion shoots of less than 0·5 cm. diameter are relatively less suitable for side-grafting in mangoes. In order to verify this inference, the scions used for the comparative trial on budding and side-grafting (Table IX) were classified according to their diameter measurements and the figures of take of each of these classes are presented in Table XI.

TABLE XI

Analyses of take according to scion diameter measurements

(Mango side-grafting trials)

Variety	Scion diameter	Percentage take
Alfonso	Above 0·5 cm.	93·55
	0·5 cm. and below	41·18
Erramulgoa	Above 0·5 cm.	79·17
	0·5 cm. and below	36·00

These figures again confirm the previously recorded inference that scions of less than 0·5 cm. diameter are of little value for mango propagation by side-grafting.

The above inferences are further borne out from the observations recorded from a separate trial with Bangalora and Neelum scions side-grafted in September 1939 in nursery beds. With thicker scions, the former variety has produced a take of 65·5 per cent and the latter 70·0 per cent, while with thinner scions of 0·5 cm. diameter and less, the take has been 24·0 per cent and 41·7 per cent, respectively. It is therefore seen that thinner scions have to be

definitely discountenanced. It would also seem that certain varieties respond to this method of propagation to a much better degree than others.

The results of the side-grafting trials in July and August in the nursery beds were so encouraging that it was considered desirable to investigate the possibility of this propagational method with seedlings grown in pots. Trials were accordingly carried out for a period of four months commencing from August 1939. A total number of 373 scions of different varieties were inserted towards the end of August or early in September 1939, another batch of 193 scions was inserted in October 1939 and a third batch of 42 scions was inserted in November 1939. The analyses of take in these various batches consisting of scions of different varieties are given in Table XII.

TABLE XII

Analyses of take from the rough mango side-grafting trials in pots from August to November 1939

Month	Percentage of take			
	Terminal scion with diameter of over 0.5 cm.	Terminal scion with diameter of 0.5 cm. or below	Mid-portion of scion shoot with diameter of over 0.5 cm.	Mid-portion of scion shoot with diameter of 0.5 cm. or below
August-September 1939	68.8	28.5	19.4	10.7
October 1939	31.9	9.5	Nil	Nil
November 1939	Nil	Nil	Nil	Nil

These results further confirm the value of thicker scions having a diameter measurement of over 0·5 cm. in side-grafting operations. They also show that the take with terminal parts of the scion shoot is very much higher than with the lower or mid-portions of the same scion shoots. The failure of all scion shoots side-grafted in November as well as the extremely low take recorded in October are attributed to the heavy precipitation received during these months. More than half of the rainfall for the year, amounting to 18·76 inches, was recorded during these two months, when rains fell over a total number of 24 days. There seems to be, therefore, some evidence in support of the belief that rainy weather is not congenial for this operation. It is also obvious from the data obtained from the various trials that certain seasons are more suitable than others for side-grafting purposes.

Subsequent observations on the growth of the side-grafts have shown that the plants are extremely slow in producing elongation growth in pots, so much so, that none of the side-grafts worked from August to November in pots became ready for setting out in the field till March 1940, whereas some of the side-grafts raised in beds during July-August became ready for planting out within about 3½ months after side-grafting. It has, therefore,

been found necessary to transplant all the side-grafts from pots into nursery beds, and this was done in March 1940.

Apart from the high take obtained by side-grafting in certain seasons, and the relatively cheapness of the operation, one special advantage associated with this method of propagation and budding is that it enables the raising of trees vegetatively even though the parent trees are situated at a distant place. A few plants have been successfully raised by side-grafting in November 1939 with scion wood obtained from Mayavaram and inserted at the Fruit Research Station, Kodur, after three to five days of separation from parent trees.

Other methods of propagation

A. Double-working

Double-working being a necessary operation in top-working of grafted trees of inferior quality, a knowledge of the relationship between the various combinations of varieties used as rootstock, intermediate stem-piece, and ultimate scion is essential. Trials on double-working form also a natural complement to the trials on root-grafting, as double-worked root-grafts are believed to enjoy greater uniformity than the grafts on vegetatively propagated rootstocks.

Preliminary trials were, therefore, initiated in May 1937 and were continued till the following October. Every month, six grafts of Neelum and six of Bangalora were selected for this purpose, and these were double-grafted with scions of Bangalora and Neelum respectively. The results are shown in Table XIV.

Table XIV

Percentage of success in mango double-grafting from May to October 1937

Varieties Rootstock × Intermediate scion × Ultimate scion	Percentage of success					
	May	June	July	August	September	October
Country × Neelum × Bangalora . .	100·0	100·0	16·7	83·3	83·3	83·3
Country × Bangalora × Neelum . .	100·0	100·0	66·7	100·0	83·3	67·7

The number of individuals being small, the results have not been subjected to a statistical test. Nevertheless, the above figures clearly indicate that double-grafting is an easy operation and produces a very high success practically in all the months in which the trial was carried out. The reason for the low success in July 1937 in one set is, however, inexplicable.

The success obtained during 1939-40 by double-grafting with Neelum and Bangalora as ultimate scions has been mentioned previously while comparing this method with root-grafting. It was also brought out then that double-grafting is both an easy and convenient operation.

B. Cleft-grafting

As reported previously, this method gave only a take of 0·85 per cent in each with Neelum and Bangalora scions during 1939-40 trials. The trials were conducted in July 1939 on one-year-old seedlings, and 104 seedlings

were utilized for cleft-grafting with each of the two scion varieties. From these it is concluded that cleft-grafting has proved almost a total failure at this Station.

C. Cuttings

During 1936, a large number of mango cuttings were planted in different seasons to find out if rooted mango cuttings can be successfully raised in this tract ; but the results were totally disappointing. In the following year a preliminary trial with 25 cinctured cuttings was initiated in September and October 1937 to test the rooting ability of such cuttings. Of these, six put forth fresh growth and three developed into vigorous rooted plants. Examination of one of these plants about four months after planting revealed, surprisingly, a fairly good root formation (Plate II, fig. 4).

In a separate trial, a total number of 592 cuttings from young and old trees ringed during nine successive months in 1937 were planted in nursery beds in order to collect observations on the influence of the age of the tree and the period of ringing and planting on the rooting of the cuttings. At the request of Messrs Imperial Chemical Industries, Ltd., 225 cuttings of mangoes were also planted in that year after dipping in Hortomone A, a proprietory product reported to be efficacious in inducing rooting. The planting of these cuttings for this trial was done in July 1937. None of the cuttings in these two trials rooted, although a few did show signs of growth activity for one or two months after planting only to wither away without forming any root-system. These trials were followed up by another in November 1938 with 250 cuttings of two mango varieties, ringed and planted two months after ringing operation and after treating some with anhydrous lanolin for 20 hours, some with 1/10,000 of B-indolyl acetic acid for 20 hours and some more with 1/20,000 of the last mentioned solution. Excepting for some evidence of the formation of root initials on four cuttings, none of these treatments has also indicated its usefulness for the purpose in view. It was, therefore, considered idle to pursue these trials any further.

D. Vegetative propagation of rootstocks

In order to determine the possibility of inducing the etiolated parts of mango plants to root and thus produce clonal rootstocks, 141 mango plants (72 seedlings and 69 grafts) were planted on different occasions from May to October 1937 in nursery beds and these were gradually pegged down and earthed up after they had fully established themselves in their new surroundings. As new shoots sprang up from these plants, they were etiolated and subsequently cinctured by tying around a thin piece of wire, and were again earthed up. None of the ten etiolated and cinctured shoots rooted up to the end of 1937, even though some were cinctured as early as August 1937. The method as followed, therefore, was not encouraging.

The combined practice of etiolating and cincturing, however, continued to be under trial during the following year with a view to ascertaining its suitability for raising mango rootstocks. As in the previous year, these methods proved to be totally disappointing, as not a single shoot out of the 20 etiolated and cinctured at two different periods of 1938 gave any evidence of new root formation.

PERFORMANCE OF TREES PROPAGATED BY DIFFERENT METHODS

In order to study the extent of uniformity in, and the orchard performance of, the plant material raised by some of the more important methods of propagation, an experiment was planned out in 1939. During the 1st and 2nd December 1939, 108 trees of apparently uniform size and vigour representing 18 root-grafts in each of Neelum and Bangalora, 18 inarched plants and 18 double-grafts in each of the same varieties were planted out in an area of 4·0 acres. The lay-out consisted of six replications or blocks with six treatments randomized in each, each plot of 20ft. × 120ft. being planted to three trees of each treatment. Twenty-two budded plants and nine side-grafts of Neelum from the same scion parent as that used in the above experiment, as well as six side-grafts of Bangalora also from the same scion parent as that used in the above trial, were planted out close to the above experimental area for general comparison of their performance with the trees included in the main experiment.

Growth measurements of all these experimental trees have been recorded at the time of planting and are proposed to be collected with other performance records every year in future. In order to ascertain if a variety like Neelum known to possess productive and regular bearing tendencies will transmit these desirable characters when used as an intermediate scion to a shy or irregular-bearing but choice-fruiting ultimate scion variety, and also to find out roughly the influence of double-working on precocity, tree size and tree performance, a small but separate observational trial with 28 double-worked mango trees was initiated in 1940. Four ultimate scion varieties, viz. Himayuddin, Jahangir, Allampur Baneshan and Mulgoa, have been included in this trial with Neelum as intermediate scion for all. The growth and performance of the trees in this trial plot are also being watched with interest.

DISCUSSION

The widespread commercial practice of raising grafted mango plantations in this country is due to the well-known fact that most of the Indian mangoes are mono-embryonic, and therefore their progenies are very variable. It has been proved from the present investigations that several polyembryonic mango races exist in the west coast of south India, and these should be able to transmit their characters to their progeny in a remarkable degree. Sen and Mallik [1940] have also corroborated the above findings, although these workers were not able to obtain as large a number of seedlings per seed from most of the South Indian polyembryonic races as at Kodur, possibly due to the delay in sowing of stones. Unfortunately, most of these polyembryonic races bear relatively inferior fruit and are consequently of little commercial importance. Nevertheless, they are of undoubted value as potential source of uniform rootstock material.

At present the Indian mango nursery trade is almost entirely dependent upon seedling rootstocks from mono-embryonic seed parents. The seedlings are being raised from fruits which are the result of open pollination. The pollen parent which plays an important part in determining the characteristics of the offspring being unknown, there is no knowing now to what extent good pollination and potent varieties are involved in the raising of our seedling

rootstock material. The result is that our seedling rootstock is an admixture with widely differing growth and cropping potentialities. Tukey [1929] has emphasized on the necessity and importance of paying attention to selection of particular varieties as seed parents for raising seedlings of cherry, peach, apple and other temperate fruits for use as rootstocks. Indication has been afforded in the present studies also that considerable variation exists in regard to uniformity and vigour of seedlings raised from different seed parents. It would therefore be necessary to pursue the studies further so as to determine the most suitable mango varieties, races or individual trees as seed parents, and also to find out the most suitable or potent varieties as male parents for each selected seed mother parent or variety.

The removal of endocarp or hard seed-coat before planting of mango seed has been advocated by Kinman [1918] in order to increase the germination percentage and to reduce the time taken for germination. These results obtained in Porto Rico have recently been confirmed by Paul and Guneratnam [1937], who assert that it has become an established practice in laying down mango nurseries in Ceylon. The latter workers [Paul and Guneratnam, 1938] have also described a convenient method of extracting kernels. As shown earlier in this paper, although shelling has much to commend it, it is nevertheless a practice that is not likely to find favour in most parts of India. Mango seeds can be usually had at very cheap rates in most parts of this country, and the nurserymen will also be reluctant to bear the additional cost on the shelling operation. The lower germination percentage obtained from shelled stones at Kodur is also a point that has to be borne in mind in this connection.

Hoblyn [1931] has given examples to show how the trees on vegetatively raised rootstocks are more uniform than those on seedlings. Vegetative propagation of rootstocks by means of cuttings was found to be a failure by Burns and Prayag [1921], while by air-layering they found the percentage of success poor, root formation meagre and after-growth and fruiting of the layers very slow. Gootee or Marcottage was also tried by these workers with no better results. In Java, ring-barking of the shoots followed by covering the shoots with earth is reported to have caused rooting of the shoots [Fielden and Garner, 1936], while in the Federated Malaya States no root formation was secured. Leh [1930] reported that in Netherlands colonies, the vegetative propagation of mango is a puzzling question. In the trials conducted at Kodur, although some success was obtained by rooting of cuttings, the method is one that cannot be advocated at present in commercial nursery practice. Air-layering and Gootee methods being expensive and tedious were not tried, nor do the reports of other workers on the value of these methods are so encouraging as to be of any commercial value [Collins, 1903]. Ringing and etiolation methods were tried at Kodur during two successive years with a varying number of Neelum, Bangalora and seedling shoots with no success.

The work of elimination of the variability from seedling rootstock has therefore to be done through means other than vegetative propagation, among which the possibilities of the polyembryonic races as rootstocks are bound to be of considerable importance. Fielden and Garner [1936] state that the polyembryonic mangoes from East Indies and Philippines reproduce themselves true from seed to such a remarkable extent that it may be assumed

that the fertilized embryo is often absent. This, if true, is a finding of very great value in excluding entirely the sexually originated seedling. Work has to be pursued further to see to what extent the above theory holds true in regard to the polyembryonic Indian races ; and if it is not true, to determine the possible methods of elimination of the sexual seedling. The root-stock value of each of our polyembryonic races is yet another fruitful line of study that needs to be intensified.

Apart from polyembryony, the value of root-grafting requires to be fully investigated as a means of removing the variability in the mono-embryonic seedling rootstock. Investigations in this line are already under way at the Fruit Research Station, Kodur, and the results when available are bound to be of interest to the workers on this fruit. Root-grafting may not have much value in commercial nursery practice, but its value for experimental purposes, particularly for the raising of uniform plant material on a miscellaneous seedling basis, cannot be denied.

In regard to the commercial methods of propagation of mango on seedling rootstocks, inarching has taken such a strong hold in this country that any other method may not easily appeal to the growers and nurserymen. The success in budding mango as reported in the present paper in certain seasons with certain scion varieties is, however, so very high that there seems little need for entertaining any further doubts about the possibilities of this method. But it is necessary to emphasize that, apart from the skill of the operator, the optimum season and the suitability of the scion varieties should first be determined before budding can be advocated on a large scale in any tract.

Side-grafting as recommended by Nakamura [Tanaka, 1939] is yet another method which can be advocated in commercial nursery practice, if the optimum season is first determined for each tract and for each variety. This method is even simpler in practice than budding and is found capable of giving an equally high take. It is being already employed successfully on a small scale for top-working larger trees in the west coast where humid atmospheric conditions prevail for a long period of the year. In drier tracts, as at Kodur, the method was found to be valueless for use in old trees, but with nursery trees, on the other hand, the method is full of possibilities if performed in a suitable season.

It is recognized that most of the investigations reported herein are not capable of furnishing information of a conclusive nature on all aspects of the problems under study. The number of questions to be elucidated was so large that considerations of economy imposed a necessity to undertake at the first instance a series of small-scale preliminary trials. The observations from these preliminary trials served as pointers for the lay-out of large-scale trials subsequently. If it is remembered that the success in any propagational method is governed by a vast array of factors, such as skill of operator, season of operation, age of the rootstock, size and nature of the rootstock and scion wood, nature of soil, kind of culture practised in nursery, variety of scion, individuality of seed and scion parent, technique of the propagational method, etc., the difficulties in the way of securing a straight and final answer to each of the various questions on each of the various propagational methods under study will become obvious. Despite all these considerations, it will be found

that from a large number of small-scale trials conducted over a number of seasons and from a few large-scale trials have emerged a fund of information of some interest and practical importance. Above all, a stage has now reached when it is possible to visualize and formulate a more definite and fruitful approach to the varied problems confronting the mango propagator than before the commencement of the present investigations.

Summary and conclusions

1. A number of seedling races of mangoes grown on the west coast of the Madras province have been found to be polyembryonic, producing two to five seedlings per seed.

2. Contrary to the popular belief, seeds of some of these polyembryonic varieties are found to produce a fairly high germination. The varieties that are likely to be favoured by nurserymen, because of their high germination capacity and polyembryony, are indicated in the text of the paper.

3. Distortion of seedling stem is found to be a common feature in mango seed-beds when unshelled stones are sown.

4. Sowing of mango stones with plumule up is found to produce in seedlings a straight tap-root and stem, both of which characters facilitate inarching and root-grafting operations.

5. Shelled stones, although they produce a straighter tap-root and stem in seedlings than unshelled stones, and are desirable for elimination of diseased or worm-infested seeds, are not advocated, because of the expensiveness of shelling operation and poor germination of shelled stones.

6. Grading of fruits or stones is not considered as a necessary operation in mango nursery practices, as neither plant vigour nor germination is found to be dependent on size of fruit or stone.

7. Measurable differences in seedling vigour and germinating capacity are noticed between the progenies of different seed parents, and it is therefore inferred that the inherent vigour of the seed parent is a dominating factor masking all possible influences as those of fruit or stone size. Selection of seed parents which produce inherently vigorous progenies are shown to lead to a saving of time and money to the nurserymen by shortening the pre-inarching period.

8. Transplanting of mango seedlings with naked roots is found to be a feasible operation under certain conditions.

9. Heavy defoliation of mango seedlings seven to nine days prior to their lifting from seed-beds has been found to reduce the casualties to the minimum extent.

10. Placing of potted seedlings close together in a trench and letting in of irrigation water thereafter at an interval of three to five days is shown to be a more economical practice than the prevalent system of hand-watering the pots daily in South India.

11. Successful inarching of young seedlings of even 4½ months of age has been found possible.

12. The popular belief that older the rootstock the greater the size of the grafts in the plantation is falsified from the data collected up to 18 months after planting on a Neelum plantation planted to trees on one day

on rootstocks of three different ages, viz. $10\frac{1}{2}$, $13\frac{1}{2}$ and $16\frac{1}{2}$ months at the time of grafting. It is, however, possible that these results may not apply to grafts on very young rootstocks of the type mentioned in the foregoing paragraph.

13. Neelum has contributed to a greater success by inarching than Bangalora.

14. Weather conditions seem to influence to a great extent the success in inarching operation, July-September having proved the optimum and June the worst period for Neelum in 1936.

15. The optimum period from the date of inarching to that of separation from scion parent is found to differ with different varieties, Rumani having shown to demand a longer period than Neelum and Bangalora.

16. It was found possible to plant out grafts in their permanent orchard sites immediately after separation from scion parents during certain seasons. An earlier manifestation of flush was noticed in such grafts than in those which were nursed for a time prior to planting. The appliction of results to all grafts raised under diverse conditions must, however, await results of further investigation.

17. A method of root-grafting in mangoes has been devised successfully, and is described in the text.

18. (*a*) The relative amount of success obtained by root-grafting, double-working, inarching, shield and patch-budding, and cleft-grafting in a comparative trial is presented in the text.

(*b*) On the basis of a number of trials with several methods of budding it is concluded that, budding and side-grafting can both be successfully and advantageously adopted in open beds during certain seasons. Different mango varieties are seen to respond differently to budding operation ; and among the varieties so far tested, Neelum and Erramulgoa have proved to be more suitable for propagation by budding than Bangalora and Alfonso.

(*c*) In side-grafting, the superior value of scions from apical regions of the shoots and of 0·5 cm. or over in diameter has been proved over those from lower parts of the scion shoot and thinner scions respectively. Indication has been afforded that rainy weather does not provide congenial conditions for side-grafting operation. A few plants have been successfully raised by side-grafting with scion wood obtained from a long distance and inserted after three to five days of separation from parent trees.

(*d*) Cleft-grafting and mound-layering after etiolating and ringing of shoots have proved almost a total failure, while double-grafting has been found to be an easy operation producing a very high success in several months.

(*e*) Although success obtained is very low, it is now proved that mango can be raised by hard-wood cutting. Certain growth-promoting substances, which were tried, have not proved efficacious in inducing root-formation in mango cuttings.

19. To study the extent of uniformity in the trees raised by root-grafting, inarching and double-working, and the relation between propagational method and orchard performance, a comprehensive trial has been laid out. In a separate trial under progress, the role of intermediate rootstock in double-worked plants, particularly in increasing tree productivity, is being studied.

Acknowledgements

The experiments reported in this paper have been carried out at the Fruit Research Station, Kodur, with the funds of the Imperial Council of Agricultural Research to whom the author's thanks are due. The Assistants of Fruit Research Station, Kodur, and a few Farm Managers sent to the Station for training by the Madras Department of Agriculture have rendered assistance in the conduct of these various trials at different stages of their progress. The author desires also to record his thanks to all these persons, specially to Mr N. Venkatadri Reddy, who was in charge of propagation of plants for the purpose of most of the experiments and also assisted in carrying out some side-grafting and budding trials.

References

Burns, W. and Prayag, S. H. (1921). *The book of the mango*: Govt. Central Press, Bombay

Collins, G. N. (1903). *Bull. U. S. Dept. Agric. Bur. Plant Ind.* No. **28**

Fielden, G. St. Clair and Garner, R. J. (1936). *Imp. Bur. Fruit Production Tech. Comm,* No. **7**

Grubb, N. H. (1927). *East Malling Res. Sta. Ann. Rept., 1925*, pp. 11-5

Hatton, R. G. (1932). *Imp. Bur. Fruit Production Teh. Comm.* No. **3**

Higgins, J. E. (1906). *Bull. Hawaii Agric. Expt. Sta.* **42**

Hoblyn, T. N. (1931). *Imp. Bur. Fruit Production Tech. Comm.* No. **2**

Kinman, C. F. (1918). *Bull. Porto Rico Agric. Expt. Sta.* No. **20**

Knight, R. C. (1927). *East Malling Res. Sta. Ann. Rept., 1925*; *Supplement*, pp. 51-63

Leh, van der (1930). *Rept. and Proc. 9th Internat. Hort. Congress (The Royal, Hort. Soc.), 1930*

Paul, W. R. C. and Guneratnam, S. C. (1937). *Trop. Agric.* **88**, 86-91; 331-7

——— (1938). *Trop. Agric.* **90**, 34-5

Popenoe, Wilson (1927). *Manual of tropical and sub-tropical fruits*: The Macmillan & Co. New York, pp. 79-145

Sen, P. K. and Mallik, P. C. (1940). *Proc. 27th Ind. Sci. Cong., Madras, 1940*, Part III: *Abstracts* **43**, 142-3

Swarbrick, Thomas (1930). *J. Pom. and Hort. Sci.* **8**

Swarbrick, Thomas and Roberts, R. H. (1927). *Wisconsin Agric. Expt. Sta. Res. Bull.* **78**

Tanaka, Tyozabura (1939). *Philip. J. Agric.* **10**

Tukey, H. B. (1929). *Bull. New York State Agric. Expt. Sta. Geneva*, No. **569**

Whittaker, E. C. (1940). *Agric. Gaz. N. S. Wales* **51**, 331-6

Woodrow, Marshall (1904). *The mango. Its culture and varieties*: Parsley Alexander Gardner, London, pp. 1-32

Wray, G. W. (1939). *J. Jamaica Agric. Soc.* **43**, 94-5

THE COLD STORAGE OF PEARS (BARTLETT) IN THE PUNJAB

BY

LAL SINGH, B.Sc. (Hons.), M.Sc. (Calif.)

Fruit Specialist, Punjab

AND

ABDUL HAMID, M.Sc. (Hons.)

Research Assistant

(Received for publication on 13 March 1941)

(With Plate XL and one text-figure)

In the Punjab, different varieties of pear are grown, e.g. Bartlett, Dutchess of Bordeaux, Easter Beurre, etc., in the hills ; *Kashmiri nakh* and *Pathar nakh*, (sand pear) in the plains. In the Kulu valley, the Bartlett is far more popular with the growers than any other variety, and is grown from 4,000 ft. at Kulu, to 6,000 ft. at Manali. This variety is also grown in other parts of India and in fact is largely grown all over the world. In the plains, however, the *Kashmiri nakh*, a recently introduced variety, promises a good future and is even now exported to other provinces.

Pears grown at higher altitudes are much superior in quality to those grown in the plains. Bartlett or Williams pear, a mid-season variety , is excellent for canning and table purposes. It is fairly big in size, very delicious, creamy, sweet in taste, when ripe, with a pleasant aroma. The fruit is very delicate, and when full ripe deteriorates within a few hours.

The Kulu growers, however, have to face certain practical difficulties in the disposal of this fruit, i.e. limited demand for the fruit in the Kulu valley, high transportation charges and the ripening difficulties. Most of this fruit has to be sent out of the valley as there is very little demand for this fruit in Kulu proper. But the grower has to pay very high transportation charges for sending the fruit to the plains, due to transportation monoply and high taxes which, however, are expected to be reduced shortly. The ripening difficulties are also a great handicap in as far as, if the grower sends the fruit in ripe condition, it deteriorates rapidly in the way. But if he sends the fruit in unripe condition to the hot plains of the Punjab, where the temperature varies from 95 to 110° F. at that time the fruit does not ripen and merely shrivels up with the result that the fruit in the glut of the season and in normal years fetches ridiculously low price of eight annas to one rupee per maund in Kulu market. Sometimes it does not even pay to pick the fruit and send the same to the market, with the result that a good deal goes to the manure pit. For this very reason the area under pear is not increasing although there is any scope for expansion of area under this fruit. On the other hand, fruit being of very high quality, is greatly relished by the people in the plains and can fetch good price there.

In order to make pear-growing a paying proposition, both in the interest of the grower and the consumer, it was considered necessary to study (*a*) the optimum stage of maturity at which the fruit should be picked and the test for the same, (*b*) handling of the fruit in transit, (*c*) best temperatures for the storage of the fruit of different stages of maturity and effect of disinfecting the fruit and wrapping the same on the storage life of the fruit, (*d*) diseases to be confronted in storage, (*e*) optimum temperature required for the ripening of the fruit after removal from cold storage, (*f*) effect of certain gases in hastening the ripening process of the fruit, and lastly (*g*) the possibilities for cold storage industry. Bartlett pear was thus selected for experimental purposes. These problems were investigated during the past two years, viz. 1938-39, at Lyallpur, under the research scheme 'Cold Storage of Fruits in the Punjab', financed jointly by the Imperial Council of Agricultural Research and the Punjab Government. The relative information available from these experiments and others conducted at the Agricultural Research Institute, Lyallpur, is given in the following few pages. In order to give a more complete information to the reader on the subject, effort has also been made to give necessary information available in literature.

The time of picking and maturity tests

Bartlett variety of pear, which was selected for these experiments, is generally ready for picking at the end of July or beginning of August at Kulu, as was determined by the experiments, conducted under the fruit and vegetable preservation scheme, financed jointly by the Punjab Government and the Imperial Council of Agricultural Research. At higher altitudes, however, the ripening is about a week later. The time of picking the fruit in the valley is thus very short and a large bulk of the fruit is harvested within a short space of time.

In America [Magness, 1929], where the pear industry is of very great magnitude, certain criteria, found out by scientific research, are widely adopted for picking the fruit at the appropriate stage of maturity. In this country, however, the fruit is picked by the naked eye judgement, a method which is hardly satisfactory. Experiments conducted here have shown that the fruit should be picked at a stage when it is hard, green, mature and no further changes except ripening processes are to occur, so that it is not easily bruised in transit and ripens properly at the destination.

Various chemical tests, viz. sugar-acid ratios, etc., have been carried out in other countries [Magness, 1929] to find out their relationship with the ripening processes, but no concordant results have so far been found in this direction. In the United States of America [Magness, 1929] there has been found a type of penetrometer commonly known as 'pressure tester' (Plate XL) which measures the resistance of the fruit flesh to a penetrating knob of 5/6 in. in diameter connected to a registering pressure gauge. This knob penetrates the fruit to a depth of 5/6 in. It has been found to be a very useful and handy instrument, the readings of which bear a close relationship to softening of the fruit and its stage of maturity. Trial tests carried out with this type of penetrometer at Kulu (under the fruit and vegetable preservation scheme, Punjab and I. C. A. R.) have shown that for satisfactory transport of fruit to the Punjab plains, Bartlett pear should be picked at a pressure test of about 16-18 lb.

Pressure tester

In addition to the pressure test, the colour of the fruit and the cork formation in the lenticels are good indices that the fruit is ready for picking. A colour chart has also been devised in America [Magness, 1929] which is also very useful. The immature pear has a deep green colour, but when mature it shows a slightly light green colour with only a tinge of yellow in-between the lenticels. The lenticels of immature pear are white and as the fruit matures, cork formation takes place and the lenticels become brown in colour. The development of this brown colour in the lenticels is a very good indication that the fruit will ripen without shrivelling. The development of characteristic smoothness of shiny nature is also a valuable guide to the optimum picking conditions.

It has been found in the United States of America that both the early and late picked pears tend to scald somewhat sooner than pears picked in the mid-season. Fruit of advanced stage of maturity tends to develop breakdown earlier and in fact core-breakdown occurs earlier still, i.e. even when the outer flesh is in good dessert condition, and this emphasizes the importance of picking the fruit at the right stage of maturity.

Handling and transport

Experience and research [Magness, 1929; Van der Plank, 1937; Tindale 1938] have shown that it is better to handle the pears under coolest possible condition. Pears should preferably be pre-cooled (fruit cooled to below 40° F. very quickly) for transport and sent in refrigerated vans. But in India such means are still undeveloped and pre-cooling is almost unknown. Still the experiments carried out at Lyallpur on the storage of pears, have shown that pears picked at the right stage of maturity, even if shipped under ordinary conditions of transport, without pre-cooling, can keep long and sent to long distances provided proper ripening and storage facilities exist as will be evident in the succeeding paragraphs.

Behaviour of fruit in cold storage

Fruit of two stages of maturity, viz. A and B, was selected and stored at three different temperatures—32° F., 36° F. and 40° F. Half of the fruit was stored as such and the other half was washed with 5 per cent borax solution for 2-4 minutes. Half of the fruit of the above two lots was wrapped with tissue paper and the other half left unwrapped. Fruit of A-stage of maturity was hard, green, mature, crisp, astringent and acid in taste, pressure about 18 lb. Fruit of B-stage was of advanced maturity than A, and greenish yellow, still crisp, less astringent, slightly less hard but firm, 14 lb. pressure.

The fruits stored at 40° F. (Tables I-IV, Fig. 1) ripened normally within 20 days* in case of B-stage of maturity and 25 days in case of A-stage of maturity and remained thereafter in good condition for a week in storage. Pears rarely scalded so long as they showed even slight green colour. The fruit of A and B stages of maturity, stored at 36° F., behaved in a manner similar to that at 40° F. except that the ripening was slow. It took six and four weeks, respectively, for the fruit of A and B stages of maturity to become yellow ripe at 36° F. The fruit of A and B stages of maturity stored at 32° F. kept in excellent condition for five and four months during the first year, but in the second

*Fruit was considered as properly stored so long as the wastage did not exceed 10 per cent.

year, due to some carelessness in handling the fruit in transit, coupled with rather poor condition of the crop and small size of fruit, consequent to the shortage of rainfall, the storage life was reduced to $4\frac{1}{2}$ and 2 months respectively for A and B stages of maturity. The pears in storage gradually turn yellow and, when full yellow, they should not be retained further in storage, otherwise physiological disorders will cause a severe loss of fruit. Borax wash (5 per cent in water) and wrapping had no beneficial effect in prolonging the storage life of the fruit. At the Cold Storage Research Station, Poona, storage life of Bartlett pear from Kashmir has been found to be three months [Karmarkar, 1940].

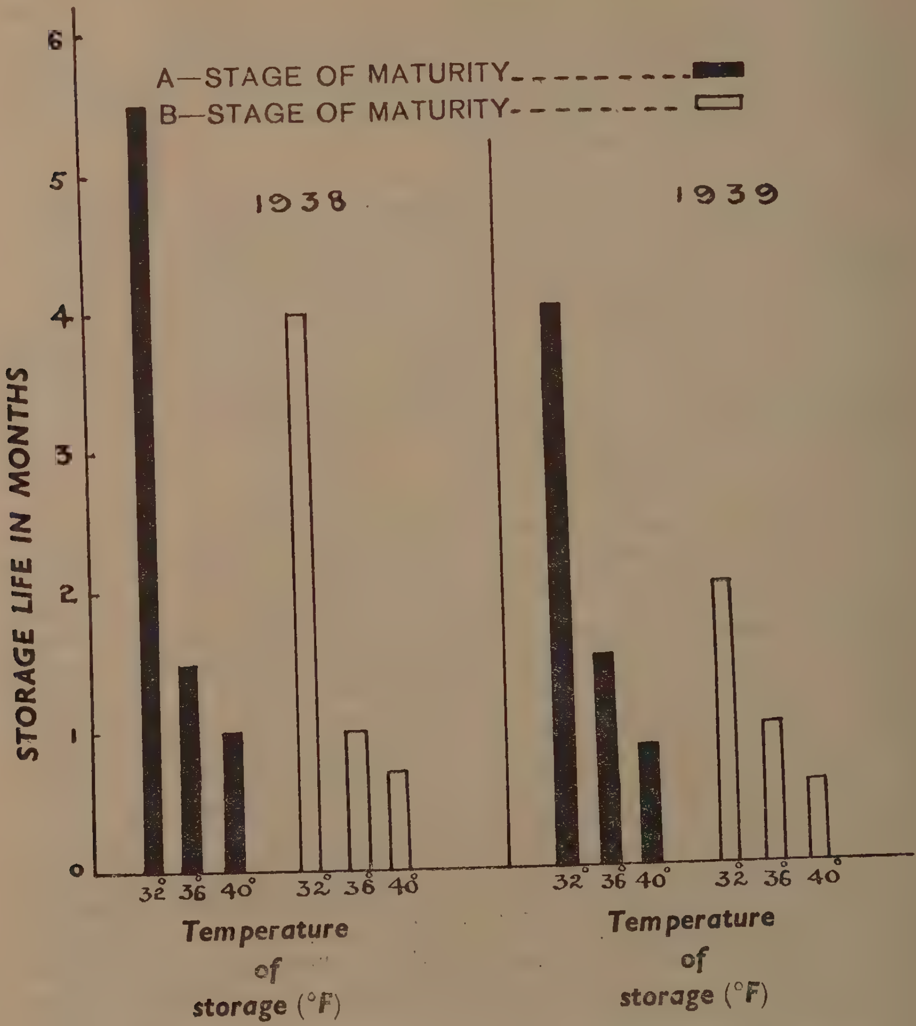


FIG. 1. Storage life of Bartlett pear at different temperatures of storage, 1938-39

TABLE I

Percentage total wastage of fruit (Bartlett pear) of A-stage of maturity, 1938

(60 fruits in each lot : stored on 4 August 1938)

No. of days in storage	Treated with 5 per cent borax						Untreated					
	Wrapped			Unwrapped			Wrapped			Unwrapped		
	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.	32° F.	36° F.	40°F.
15	0	0	5·0	0	0	3·3	0	0	6·6	0	0	0
30	0	0	33·3	0	3·4	33·3	0	5·0	25·0	0	3·3	11·7
45	0	10·0	58·3	0	11·7	50·0	0	21·7	50·0	0	8·3	25·0
60	0	25·0	...	0	23·3	...	0	25·7	...	0	16·6	...
75	1·7	33·3	...	3·3	30·0	...	0	36·6	...	0	27·4	...
90	1·7	...	...	3·3	...	...	0	...	...	0	...	...
105	5·0	...	...	3·3	...	...	0	...	...	0	...	...
115	6·7	...	...	3·3	...	...	0	...	...	0	...	...
131	15·0	...	...	5·0	...	...	0	...	...	0	...	...
150	15·0	...	...	10·0	...	...	3·3	...	...	3·3	...	...
168	21·6	...	...	15·0	...	...	10·3	...	...	10·3	...	...
180	...	...	...	25·0	...	...	23·0	...	...	23·0	...	...

TABLE II

Percentage total wastage of fruit (Bartlett pear) of B-stage of maturity, 1938

(60 fruits in each lot : stored on 4 August 1938)

No of days in storage	Treated with 5 per cent borax						Untreated					
	Wrapped			UnWrapped			Wrapped			Unwrapped		
	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.
15	0	0	0	0	0	0	0	0	0	0	0	0
30	0	1·6	15·0	0	3·3	10·0	0	0	15·0	0	0	6·6
45	0	16·7	41·6	0	13·3	45·0	0	13·3	30·0	0	11·6	23·3
54	0	48·6	...	0	41·6	...	0	38·3	...	0	30·0	...
60	0	...	...	0	...	...	0	...	...	3·0	...	...
75	5·0	...	...	1·7	...	...	0	...	...	3·3	...	...
90	5·0	...	...	1·7	...	...	0	...	...	3·3	...	...
105	13·3	...	...	1·7	...	...	3·3	...	...	6·7	...	...
115	13·3	...	...	6·6	...	...	6·6	...	...	10·0	...	...
131	20·0	...	...	11·6	...	...	16·6	...	...	16·6	...	...

TABLE III

Percentage total wastage of fruit (Bartlett pear) of A-stage of maturity, 1939

(72 fruits in each lot : stored on 14 August 1939)

No of days in storage	Treated with 5 per cent borax						Untreated					
	Wrapped			Unwrapped			Wrapped			Unwrapped		
	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.
20	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	20·8	0	0	16·7	0	0	19·4	0	1·4	9·7
40	0	15·0	60·0	0	9·7	58·3	0	5·6	55·5	0	1·4	50·0
56	4·2	87·5	...	1·4	80·5	...	1·4	79·2	...	0	50·0	...
71	9·7	...	...	1·4	...	...	4·2	...	...	0	...	...
93	12·5	...	...	2·8	...	...	6·9	...	...	1·4	...	...
109	12·5	...	...	4·2	...	...	9·7	...	...	1·4	...	...
124	16·7	...	...	8·5	...	...	12·5	...	...	6·9	...	...
137	50·0	...	...	40·3	...	...	50·0	...	...	36·1	...	...

TABLE IV

Percentage total wastage of fruit (Bartlett pear) of B-stage of maturity, 1939

(72 fruits in each lot : stored on 14 August 1939)

No. of days in storage	Treated with 5 per cent borax						Untreated					
	Wrapped			Unwrapped			Wrapped			Unwrapped		
	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.	32° F.	36° F.	40° F.
17	0	0	0	0	0	0	0	0	0	0	0	0
30	0	5·5	26·4	0	5·5	18·3	0	5·5	20·0	0	5·5	18·0
41	0	44·4	...	0	37·5	...	0	41·7	...	0	36·1	...
48	0	...	...	0	...	...	0	...	...	0	...	...
60	18·0	...	...	15·0	...	...	15·0	...	...	9·7	...	...
75	44·4	...	...	43·1	...	...	32·0	...	...	26·4	...	...

It may be of interest to mention that during the first two years, experiments on pear were confined to only Bartlett variety. In the third year (i.e. 1940-41) trials have been started on two new late varieties, viz. Dutchess of Bordeaux and Easter Beurre, which were placed in cold storage (at 32° F. and 36° F.) on October 10 and 29 respectively. Dutchess of Bordeaux at 32° F. remained in excellent condition until the middle of February and Easter Beurre is in excellent condition even uptil now, i.e. beginning of March. Detailed results on these varieties will be given in a later publication.

In Australia and England [Tindale, 1938 ; Kidd, 1939] storage in special atmospheres has also been tried. The storage life of pears at 32° F. in an

atmosphere of 5 per cent carbon dioxide, was enhanced by 50 per cent. Higher concentrations of this gas caused 'brown heart' trouble in pears. No work, however, has so far been done in India on gas storage of pears.

Storage diseases

The storage life of the fruit in the cold store is limited by the occurrence of various physiological and pathological diseases. The most common physiological maladies are : (1) scalding, (2) waterlogging, (3) core-breakdown, (4) frost injury or freezing, and (5) over-ripeness. Observations made at Lyallpur during the cold storage trials are briefly described in the following paragraphs :—

Scalding

Scalding or storage scald was observed most when the fruit was stored at 36° and 40° F. The skin in this case became dark brown, while the fruit was still in firm condition. The appearance of scald rendered the fruit unmarketable. If such a fruit was allowed to stand at ripening temperatures (60°-70° F.), it became brown and developed a bad flavour.

Waterlogging

This peculiar trouble was first described by Hartman [1931] in America. A trouble bearing a very close resemblance to the symptoms detailed by Hartman was observed at 32° F. during the cold storage trials at Lyallpur.

The fruit in this case developed a 'glassy, waterlogged' appearance and the breakdown occurred in a definite zone around the core, while the rest of the tissue looked healthy. The glassy appearance in some cases was manifest near the skin but was more common near the core. The fruit, when removed from cold storage to ripening chamber, did not ripen but became brown and pulpy. This disease was more severe in the fruit of advanced stages of maturity

Core-breakdown

The core-breakdown is closely related to waterlogging effect described above. The core area in this case was discoloured and the pulp became mashy. It was manifest at 36° and 40° F.

Frost injury or freezing of pears

Although we have not come across this type of injury in the experiments at Lyallpur, yet in other countries [Hartman, 1937] this trouble has been observed. Pears subjected to low temperature—below 32° F.—either in transit or in storage (due to the presence of 'air pockets' at exceedingly low temperatures) often freeze. The pears when put in the market, become pulpy and are thus ill-suited for marketing. If the core temperature has not gone below 25° F. during freezing, the fruit can be brought back to its normal state if it is subjected to suitable temperatures above freezing point of water. In this connection Hartman [1937] states 'Thawing may be carried out at any temperature between 33° and 65° F. provided the humidity is farily high'. Frozen pears are easily injured and should be handled with great care and thawed by placing them in a single layer or in two.

Over-ripeness

The tissues of the fruit pass through a prime eating condition and gradually soften until the fruit becomes over-ripe, pulpy soft ball, which bursts even if slightly touched.

In addition to the physiological troubles, fungal pathogens were also observed during the storage trials at Lyallpur, but the attacks were never severe. Mostly these fungi were saprophytes (growing on dead and decaying tissues), such as blue and green moulds.

Optimum temperature for ripening

As stated previously the fruit, when picked from trees in ripe condition, cannot be transported without spoilage, but if it is picked in unripe condition and sent to the hot plains, it does not ripen properly, due to high temperatures. The experiments at Lyallpur have shown that fruit ripens best when stored at 60°-70° F. It has also been shown that fruit of A-stage of maturity can be kept for about 4½ months when stored at 32° F., i.e. from August to December or even later. This fruit, after removal from cold storage, has, however, to be conditioned, i.e. allowed to ripen, before it can be put in the market for sale. The best temperature for this has also been found to be 60°-70°F., i.e. just the room temperature in winter season in the plains when the fruit ripens within four to seven days. This is in conformity with the results obtained in other countries [Lutz and Culpepper, 1938]. The ripening rate decreases with lower or higher temperatures than 60°-70° F. The pears should not be allowed to ripen fully for disposal in the market but they should be let out a little bit earlier so that they reach the consumer when they are just ripe.

Artificial ripening

During ripening, certain esters and ethylene gas are evolved [Hansen and Hartman, 1937 ; Van der Plank, 1937 ; Lutz and Culpepper, 1938 ; Tindale *et al.*, 1938 ; Kidd and West, 1938 ; Bane, 1938 ; Kaltenbach, 1939 ; Hansen, 1939], the latter is mostly responsible for starting ripening changes in most of the fruits and in certain cases hastens such processes. In other countries ethylene gas is now largely used in hastening the ripening and colouring of many kinds of fruit [Kidd, 1938]. A concentration of one in 5,000-20,000 parts per volume of the gas is considered to be an optimum dose for colouring and ripening purposes, depending upon the kind of fruit, temperature of storage and the extent of leakage of gas in store. In case of pears, ethylene has a very decided effect on the softening of the flesh. But this effect is confined to the period preceding storage. No increase in the rate of ripening can be expected in pears which have been previously held at cold storage temperatures for some time. No experiments in this direction have been carried out at Lyallpur and above are some of the observations recorded in the literature on the subject.

Economic aspects

The cold storage plant of Lyallpur is of a very small size and is designed only for experimental purposes to find out the best temperature for storage, etc. The running cost of this plant will not give a true picture of the cost of

storage on commercial scale. It may be mentioned that in other countries [*Refrigerating data book*, 1934] storage expenses vary from three annas to eight annas per maund, per month. Even if the cost of storage in India may come to Re. 1 per maund, per month, it is clear that even after deducting transportation and other charges, a good margin of profit should accrue, as pears of even most ordinary quality fetch eight annas or more per seer in the market, during December-January and higher still in February-March. With the help of cold storage facilities, pear industry can be developed to a great extent. Pears picked hard, green, mature at a pressure test of 16-18 lb. (during the first week of August), and transported as such, can be conditioned at 60°-70° F. for immediate disposal at the destination, stored at 36° F. for marketing during next month and at 32° F. for the rest of the three months (October, November and December) for further sale.

Pears picked and stored in the above manner can also be profitably used for canning purposes and canning period is greatly increased thereby. Pears ripened under cool conditions develop more pronounced flavour and uniformity of texture than the fruit ripened under ordinary conditions. The canning operation should be completed as soon as possible after the fruit is sufficiently ripe, otherwise loss of fruit occurs from core-breakdown. At the Cannery of the Agricultural College and Research Institute, Lyallpur, the pears are first conditioned in cool storage for getting a product of unifrom stage of maturity and flavour and then canned.

REFERENCES

Bane, R. (1938). *Rept. Fd. Invest. Bd.* (*London*) *1938-39* (*Hort. Abst.* March 1940).
Barker, J. and Furlong, C. R. (1937). *Fd. Invest. Bd.* (*London*) *Lealfet No.* **7**
Hansen, E. (1939). *Plant Physiol.* (*Hort. Abst.* March 1940)
Hansen, E. and Hartman, H. (1937). *Plant Physiol.* **12**, No. 2
Hartman, H. (1931). *Agric. Expt. Sta. Oregon State Agric. College* (*Corvallis*), *Sta. Bull.* **282**
——————(1937). *Ice and Refrigeration*, October 1937.
Kaltenbach, D. (1938). *Int. Rev. Agric.* **29** (March), T-81
Karmarkar, D. V. and Joshi, B. M. (1940). *Indian Farming* **1**, No. 4
Kidd, F. and West, C. (1938). *Rept. Fd. Invest. Bd.* (*London*), *1938-39*
Kidd, F. ; West, C. ; Griffiths, D. G. and Potter, N. A. (1938). *Rept. Fd. Invest. Bd.* (*London*) *1938-39*
Kidd. F. ; West, C. ; Griffiths, D. G. and Potter, N. A. (1940). *Ann. Bot.* **1**, **30**
Lutz, J. M. and Culpepper, C. W. (1938) *Tech. Bull. U. S. Dept. Agric.* **590**
Magness, J. R. ; Diehl, H. C. and Allen, F. W. (1929). *Tech. Bull. U. S. Dept. Agric.* **140**
Martin, W. E. (1937). *Bot. Gaz.* **99**, No. 1
Scupin, L. (1938). *Calbe A. S. Mitteilung* No. **36** (Reprint from *Obst. Und Gemus* **2**, February 1938)
Soc. Amer. Refrig. Eng. (1934). *Refrigerating data book*
Tindale, C. B. ; Trout, S. A. and Huelin F. E. (1938). *J. Dept. Agric. Victoria* (*Australia*) (*Bull. Int. Inst. Refrg.* **4** : 1938)
Van der Plank, J. E. (1935). *J. Pom. & Hort. Sci.* **13**, 223

CITRUS MANURING

I. FERTILIZER EXPERIMENT WITH SWEET ORANGE (MALTA) GROWING ON ROUGH LEMON

BY

LAL SINGH, B.Sc. (Hons.), M.Sc. (Calif.)
Fruit Specialist, Punjab, Lyallpur

BAL SINGH, B.Sc. (Ag.), M.Sc. (Calif.)
Assistant Fruit Specialist, Punjab, Lyallpur

AND

ABDUL AZIZ KHAN, B.Sc. (Ag.), Ph.D. (Bristol)
Fruit Section, Lyallpur

(Received for publication on 25 October 1939)

(With one text-figure)

THE manurial problem of fruit trees has been studied, perhaps, in lesser detail than any other problem of practical importance pertaining to fruit culture, due primarily to the many difficulties which arise in the conduct of such investigations. Studies of manurial problem by chemical analysis of plant organs and pot experiments have their own limitations and in consequence are not wholly satisfactory. Field experiments are more reliable as these represent natural conditions under which the fruit trees are grown, but owing to the elaborate technique in the lay-out, required of this method, this phase of study has received rather inadequate attention from workers in this field of research. Even if extreme precautions are taken in the preparation of the material and selection of uniform soil, etc. it is not uncommon to find, after the orchard has been established, a considerable variation from tree to tree both in regard to yield and productivity, and such variability has often been attributed to the individuality of trees. Batchelor, Parker and McBride [1928] report that in California an extensive fertilizer trial was started on land the history of which was known for a period of about 40 years before the trees were planted for the purpose of investigation. The land received uniform cultural treatments during this period. In the preparation of the rootstock culling of the under-sized plants was done twice, once at the time of transplanting and again one year after transplanting. A third culling was done at the time when the budded plants were removed to the orchard. Extreme care was exercised in the selection of scion wood also. After the trees were planted, no manurial treatment was given to them for a period of about ten years to find out whether the trees were uniform, but it was found that in spite of all these precautions there was a considerable variation from tree to tree both in regard to growth and productivity.

As far as we are aware, no manurial work of importance on citrus has been done in India so far, but a few workers in other countries have carried out such investigations. Kinman [1915] reports that in Porto Rico a complete fertilizer consisting of nitrogen, phosphoric acid and potash gave the best results. It may, however, be added that the experiment was conducted on a heavy soil devoid of humus and lacking in all the important plant foods. The climate was hot and humid with an annual rainfall of 75 in. well distributed throughout the year. The heavy rainfall favoured the washing away of the top soil. Vaile [1922] reports from California that nitrogen alone proved to be the limiting plant food element and the plots which did not receive nitrogen failed to produce a commercial crop after a few years. Phosphoric acid or potash, singly or together, had no beneficial effect on either the health of the trees or the yield. Again Vaile [1924] collected data from about a thousand citrus growers in California for a period of five years and reports that yield of trees was in proportion to the quantity of nitrogen applied. Booth [1928] mentions that all fertilizers containing nitrogen gave an increased yield in proportion to the amount of nitrogen they contained, and phosphoric acid or potash did not improve the quality of fruit. Chapman [1934] reports that the use of phosphate or phosphorus containing material in nine different field trials on citrus for periods of 5-20 years has in no case resulted in significant increases in fruit, though the phosphate applied definitely penetrated into the root zone. It is reported in C. S. I. R. Aust. [1934-35] that fertilizer experiment conducted at Citricultural Research Station, Griffith, N. S. Wales, showed that mature but not young trees responded to nitrogenous manuring, and citrus trees did not respond to superphosphate. Morris [1936] from Rhodesia, reporting on the effect of different fertilizer treatment on the yield and quality of Valencia Late orange, concludes that nitrogen played the most important part in maintaining tree vigour, high production and good-coloured fruit The size of the fruit remained unaffected. Allwright [1937] from Western Transvaal reports that out of eight combinations of different fertilizers used, sulphate of ammonia and cattle manure gave the greatest yield. Anderssen [1937] conducted an exhaustive manurial experiment on citrus in South Africa and concluded that phosphoric acid, potash and lime did not affect the size of crop and that application of nitrogenous fertilizers caused an increased crop.

These experiments conducted in other countries on the whole go to show that out of the important constituents of plant food, nitrogen proved to be a limiting factor with regard to the productivity in citrus trees. In the Punjab, however, there is no experimental data to show deficiency of one food element or the other in the soils for citrus requirements, but by observational evidence, supported by the experience of fruit growers, one can say almost with certainty, that our soils, specially of canal colonies, lack nitrogen and it is only due to the deficiency of this nutrient element that citrus trees are devitalized and their yield reduced to a considerable extent. Whenever a dose of nitrogenous manure was administered to weak, unproductive citrus trees in several orchards, it invariably resulted in invigorating their growth and increasing their crop. Lander and others [1929] have shown that generally speaking the Punjab soils are not deficient in potash, the average

potash contents being 0·72 per cent for the whole province, while a typical sample of soil from Lyallpur contains as much as 0·827 per cent. Most of the Punjab soils have phosphoric acid lying between 0·1 and 0·3 per cent and a representative sample of Lyallpur contained 0·351 per cent P_2O_5, while American soils on the average contain 0·09 per cent of this food constituent.

The above figures show that our soils on the average are richer in potash and phosphoric acid than the American soils. It stands to reason, therefore, that these two nutrient elements cannot perhaps be the limiting factors in our case, especially when these did not have any beneficial effect on the yield of citrus fruits in a country where these are found in less abundance.

Fruit trees derive their nitrogen supply from two main sources, inorganic and organic, and with the ever-increasing area under fruits and intensive vegetable farming, the supply of organic source of nitrogen in the form of farmyard manure, which has hitherto been the only fertilizer used, is becoming very limited day by day. The purpose of these investigations was to find out if the requirements of citrus trees can be met from inorganic commercial concentrated fertilizer and also ascertain the adequate quantity required for each tree.

With the facilities provided by the Imperial Chemical Industries, Ltd., India, in giving us free supply of ammonium sulphate and placing at our disposal, by S. S. Sardar Hukam Singh, his garden, an investigation was started in 1933 at Chak 45 G. B. near Gojra, Lyallpur and continued till 1938.

Experimental material

A common variety of Malta orange (*Citrus sinensis* Osbeck) growing on seedling rough lemon (*Citrus limonia* Osbeck) rootstock was selected for these investigations from the garden of S. S. Sardar Hukam Singh at Chak 45 G. B. near Gojra, Lyallpur district. This garden comprised an area of about 35 acres under citrus at the time when the experiment was initiated and out of this area an apparently uniform piece of land of about three acres was selected for the investigations and divided into seven sub-plots the details of which are shown in the plan in Fig. 1. Twenty-four uniform trees were earmarked for each of the four treatments, viz. control, 4-lb., 8-lb. and 12-lb. doses of ammonium sulphate. As is clear from the plan a row of trees at the extremity of each sub-plot, a row at either side of the watercourse and a guard row all along the extremity of this area were excluded from the experimental trees.

The lay-out of the experiment is not in strict conformity with the requirements of modern field technique. However, the method of selecting the material was such as to reduce the variation to the minimum. Extreme uniformity of the piece of land of about three acres selected from an area of 35 acres, the rigid selection of only 96 uniform trees out of 501 trees, taking into account not only the growth but also the yielding capacity of each tree before allotting the experimental treatments, eliminating all rows of the trees along the watercourses, keeping a guard row between the plots subjected to different treatments to eliminate the overlapping effect of different doses of the fertilizer and lastly the low coefficients of variability of 8·52-9·28 in the material, will, it is hoped, make up for any defect in the statistical lay-out.

Twenty-four trees varying in girths from 30·4 to 40·7 cm. were selected out of the control plot, and trees practically of the same girths were selected from other sub-plots to be treated with different doses of the fertilizer. Grouping of the trees under different treatments with respect to their girth is shown in Table I, which shows clearly that the material at the outset of the experiment was quite uniform with respect to girth measurements of the trees, which is considered, by common consent, to be the most reliable index of tree growth.

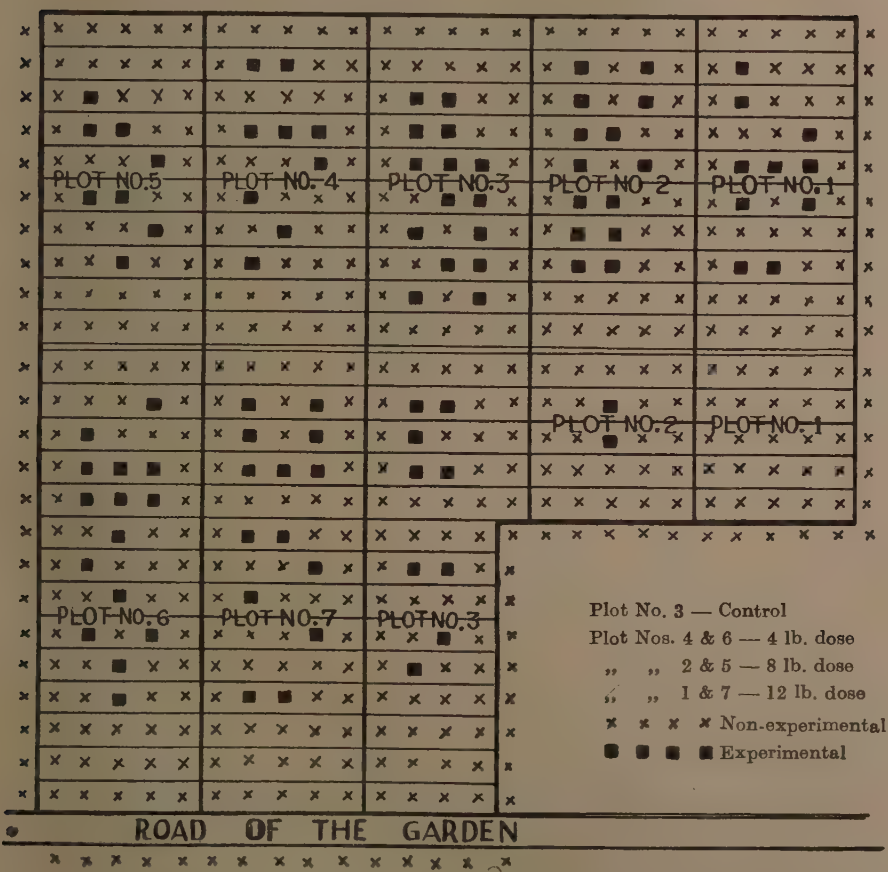


FIG. 1. Plan of the manurial experiment at Chak 45 G. B., Gojra

TABLE I

Grouping of the trees with respect to their girth before these trees were subjected to different treatments

(Girth in cm. in February 1933)

Serial No.	Control	4-lb. dose	8-lb. dose	12-lb. do
1	30·4	30·8	30·0	30·0
2	30·4	31·0	30·3	30·1
3	30·4	31·0	31·0	30·3
4	31·0	31·0	31·4	30·5
5	31·4	32·2	31·5	30·5
6	31·9	32·2	32·0	31·5
7	32·0	32·5	32·0	32·0
8	32·0	32·6	32·5	32·1
9	32·4	33·0	33·0	32·1
10	32·6	33·0	33·3	33·0
11	33·4	33·5	34·0	33·4
12	33·5	34·0	34·5	34·0
13	33·6	34·0	35·0	34·4
14	33·6	34·2	35·2	35·0
15	34·0	35·0	35·5	35·4
16	35·0	36·0	36·6	35·9
17	35·8	36·5	36·9	36·0
18	36·9	36·9	37·0	36·0
19	37·3	37·0	37·0	37·0
20	37·5	38·5	37·6	37·2
21	38·5	38·9	38·2	37·3
22	39·8	40·0	38·6	38·0
23	40·4	40·0	39·4	38·0
24	40·7	41·0	40·4	40·4
Total .	824·5	835·8	832·9	820·1
Mean .	34·3	34·8	34·7	34·2

The coefficients of variability of trees under the four groups of treatment are shown in Table II. The results show that variability of the material is not particularly high.

TABLE II

Mean girth and coefficients of variability of trees under different treatments

Treatment	Mean of girth in cm.	S. E. of mean	C. V.
Control	34·3	0·65	9·28
4-lb. dose	34·8	0·64	9·04
8-lb. dose	34·7	0·60	8·52
12-lb. dose	34·2	0·58	8·54

Not only should the trees under various treatments be uniform with respect to their growth vigour but their productivity should also be similar. The mean yield records of the trees under different treatments, before the fertilizer was applied, along with standard errors of the means, are shown in Table III. The results bring out clearly that the trees with respect to their yield at the inception of the experiment were quite uniform as the difference between any two of the means is not significant.

TABLE III

Mean yield per tree along with S. E. of mean of the trees under different treatments

Treatment	No. of trees under each treatment	Mean No. of fruit per tree	S. E. of mean
Control	24	209	9·53
4-lb. dose	24	205	10·58
8-lb. dose	24	210	11·91
12-lb. dose	24	211	11·44

The trees were one year 'budlings' when planted in the garden in 1923, and since then till the experiment was started, were receiving uniform cultural treatments and never received any pruning. No manure was applied to these trees for two years before the experiment was started though previously these were receiving farmyard manure as generally practised in the locality. It may, however, be mentioned that at the time of planting, the soil contained a lot of organic matter and the deficiency of this was not evident at the time when the experiment was started. The soil is a deep loamy one, well drained and is typical of the soils met with in the canal colony.

Data obtained and methods employed

Application of the fertilizer

Three doses of ammonium sulphate, viz. 4 lb., 8 lb. and 12 lb., were applied annually per tree from 1934 to 1938 to plots under the respective treatments. The fertilizer was applied twice annually by splitting the dose into two equal halves, as Lyon and others [1923] have shown that heavy applications of available nitrates in early spring disappear from the soil by mid season, and Potter [1927] and Murneik [1928] have shown that a renewed supply of nitrogen in mid-summer increased the size of the fruit. The first application was given each year prior to blossoming, i e. in the third week of February, and the second application in the middle of May. Due to the appearance of mottle leaf on control and fertilized trees in 1937, it was considered advisable to give a supplementary basal dressing of 60 lb. farmyard manure per tree to all the trees under the experiment, including the control, and this was done in February 1937 along with the first dressing of the fertilizer during that year. The method of applying the fertilizer was to weigh the dose separately to be applied to each tree, mix an equal amount of canal silt with it and broadcast the mixture around the tree extending about two feet beyond the spread of the branches. In a radius of 1½ ft. all around the trunk, no fertilizer was applied. The fertilizer was applied to trees under all the treatments on the same day and, after it was broadcast, was mixed in the soil with spades, and irrigation water applied immediately in basins round each tree. The basins, after these were filled with irrigation water, were closed to prevent the water from escaping. As far as practicable, an equal amount of irrigation water was applied to the trees under various treatments. It may be mentioned that the fertilizer was applied to all the trees in the sub-plots earmarked for various doses but the results have been statistically examined only in the case of those trees which were grouped at the outset of the experiment.

Girth measurements

At a height of 6 in. from the ground, trunks of the trees were marked with a circular ring of coal tar, and every year, during the month of February, girth measurements were taken at these points with a steel tape up to 1/10 cm.

Yield records

The number of fruits formed the criterion for judging the yield under various treatments. Weight, grade and quality of fruit under various treatments did not exhibit any appreciable difference and consequently were not studied in detail. The fruits were counted while on the trees during the months of September or October every year. The method of counting the fruits was to take main limbs of the tree one by one and go on marking the fruit on each limb with red clay by means of a long stick, one end of which was wrapped with cotton and dipped, when required, into a thick solution made out of the clay. Each fruit when it was marked was counted by the marker. The clay left a prominent red mark on each fruit which avoided recounting the fruits, already counted, and also ensured by rechecking that no fruit was left over uncounted.

Statistical methods employed

Each year's data with regard to both yield and girth measurements were analysed by the method of analysis of variance recommended by Fisher [1932].

	D.F.
Between treatments . . .	3
Within treatments (error) . .	92
Total .	95 (24 trees per treatment and 4 treatments)

The method of covariance was applied making use of the pre-experimental year's (1933) data to correct the experimental year's data. Differences were compared at 5 per cent level of significance.

Presentation of data

1. Girth measurements

The mean yearly girth measurements from 1934 to 1938 of the trees under different treatments are given in Table IV.

Table IV

Adjusted mean girths in cm. with their standard errors

Treatment	1934		1935		1936		1937		1938	
	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.
Control . .	36·9	0·222	38·8	0·321	39·8	0·625	41·2	0·507	41·9	0·622
4-lb. dose .	37·2	0·222	38·6	0·321	40·5	0·625	42·1	0·507	43·7	0·622
8-lb. dose .	37·5	0·222	38·8	0·321	40·2	0·625	41·6	0·507	43·3	0·622
12-lb. dose .	37·5	0·222	38·6	0·321	39·8	0·625	41·6	0·507	42·6	0·622

From Table IV critical differences for significance between the mean girths of trees under various treatments have been calculated and shown in Table V.*

Table V

Observed differences between the adjusted mean girths of various treatments and the critical differences for significance (P=*0·05*)

Treatment	1934		1935		1936		1937		1938	
	Act. diff.	Crit. diff.	Act. diff.	Crit. diff.	Act. diff.	Crit. diff.	Act. diff.	Crit. diff.	Act. diff.	Crit. diff.
Control and 4 lb. dose	0·3	0·63	0·2	0·91	0·7	1·77	0·9	1·44	1·8	1·77
Control and 8 lb. dose	0·6	0·63	0·0	0·91	0·4	1·77	0·4	1·44	1·4	1·77
Control and 12 lb. dose	0·6	0·63	0·2	0·91	0·0	1·77	0·4	1·44	0·7	1·77
4 lb. dose and 8 lb. dose	0·3	0·63	0·2	0·91	0·3	1·77	0·5	1·44	0·4	1·77
4 lb. dose and 12 lb. dose	0·3	0·63	0·0	0·91	0·7	1·77	0·5	1·44	1·1	1·77
8 lb. dose and 12 lb. dose	0·0	0·63	0·2	0·91	0·4	1·77	0·0	1·44	0·7	1·77

* In this calculation (and also in Table VII) no allowance has been made for the fact that the corrected means are no longer independent. But the application of the exact formula [Wishart] does not affect the critical difference appreciably

If comparison is made between differences of the mean girth of various treatments, it is evident that in 1934 all the three doses of the fertilizer have not significantly affected the size of the trees as manifested by girth records. The mean girths of various doses when compared among themselves have not also differed significantly from each other. In 1935, 1936 and 1937, the observed differences are all less than the critical difference for significance, and hence the treatments have not affected the girths of the trees. In 1938 the mean girth of 4-lb. treated trees is higher than the mean girth of untreated trees, there being no difference between the mean girths of control and 8-lb. treated trees, and control and 12-lb. treated trees. It may be recalled here that in 1938 organic matter was actually applied to the trees in the form of farmyard manure in the preceding spring.

2. Yield records

The mean number of fruits per tree under various treatments is given in Table VI.

TABLE VI

Adjusted mean yields in number of fruits per tree with their standard errors

Treatment	1934		1935		1936		1937		1938	
	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.
Control . .	264·8	15·09	293·8	17·72	236·4	13·12	80·0	9·77	67·9	12·41
4-b. dose . .	332·5	15·09	309·7	17·72	265·7	13·12	113·3	9·77	200·0	12·41
8-lb. dose . .	318·1	15·09	326·0	17·72	268·7	13·12	116·9	9·77	198·6	12·41
21-lbs. dose .	311·4	15·09	348·3	17·72	276·5	13·12	144·8	9·77	199·4	12·41

From Table VI critical differences for significance between the mean yields of trees under various treatments have been calculated and shown in Table VII.

TABLE VII

Observed differences between the adjusted mean yields of various treatments and the critical differences for significance (P=*0·05*)

Treatment	1934		1935		1936		1937		1938	
	Act. diff.	Crit. diff.	Act. diff.	Crit. diff.	Act. diff.	Crit. diff.	Act. diff.	Crit. diff.	Act. diff.	Crit. diff.
Control and 4 lb. dose	67·7	42·91	15·9	50·39	29·3	37·28	33·3	27·79	132·1	35·29
Control and 8 lb. dose	53·3	42·91	32·2	50·39	32·3	37·28	36·9	27·79	130·7	35·29
Control and 12 lb. dose	46·6	42·91	54·5	50·39	40·1	37·28	64·8	27·79	131·5	35·29
4 lb. and 8 lb. dose	14·4	42·91	16·3	50·39	3·0	37·28	3·6	27·79	1·4	35·29
4 lb. and 12 lb. dose	21·1	42·91	38·6	50·39	10·8	37·28	31·5	27·79	0·6	35·29
8 lb. and 12 lb. dose	6·7	42·91	22·3	50·39	7·8	37·28	27·9	27·79	0·8	35·29

Table VII shows that in 1934 all the three treatments, i.e. 4 lb., 8 lb. and 12 lb. doses, gave significantly higher yield than control, whereas there was no significant difference between the mean yields of various doses. In 1935 the differences between the yields of control and 4 lb. dose, and control and 8 lb. dose were not significantly different, while 12 lb. dose gave an increased yield over the control. The difference between the means of various doses was not significant during this year. In 1936 also the behaviour of trees under various treatments with respect to yield was the same as in the previous year, i.e. 12 lb. dose gave an increased yield over the control, there being no significant difference between control and 4 lb. dose, and control and 8 lb. dose. Also the differences between the various doses were not significantly different from one another. In 1937 all the manured trees gave higher yield than the control. Also 12 lb. dose gave higher yield than 4 lb. dose, there being no definitely significant difference between 8 lb. and 12 lb. doses. In 1938 all doses of the fertilizer gave an increased yield over control, there being no significant difference between the various doses.

3. *Relative effect of the fertilizer on the yield*

The percentage increases in yield of manured trees over the control from 1934 to 1938 are presented in Table VIII.

TABLE VIII

Percentage increase in yield of manured trees over the control

Treatment	Percentage increase in yield				
	1934	1935	1936	1937	1938
4 lb. dose . .	24·5	4·4	10·8	41·2	192·6
8 lb. dose . .	20·3	11·2	13·0	46·2	192·6
12 lb. dose .	18·1	19·0	16·8	81·2	194·1

During 1934, treated trees gave an increase over the control to the extent of 18·1-24·5 per cent. In 1935, though there was an increased yield over the control, it was not of the same magnitude as in the previous year, especially in 4 lb. and 8 lb. doses, though 12 lb. dose maintained the percentage increase to the same level as in 1934. In 1936, a slight increase in yield occurred in 4 lb. dose as compared to 1935, but it did not reach the level of 1934. In 1937, the manured trees gave an increased yield over the control from 41·2 to 81·2 per cent, the increases being in the same order as the doses. It is clear that during this year the increases in yield over the control were higher than in all the previous years. During the last year of the experiment, i.e. 1938, the percentage increases in yield of manured trees over the control were the highest recorded. An increase to the extent of 192·6-194·1 per cent was observed over the control during this year. It may be

recalled that during the preceding year, i.e. 1937, 60 lb. of farmyard manure per tree were added in addition to the usual doses of the fertilizer.

4. Yield records of all the trees in various blocks

The data presented under sub-section 2 and statistically examined relates to 24 trees each under different treatments. But it may be pointed out that yield records were kept for all the trees in various plots numbering 111 under control, 120 under 4 lb. dose, 125 under 8 lb. dose and 145 under 12 lb. dose. Since these trees were not uniform in size these were classified according to their size in different groups, viz. A, B, C and D, A being the biggest and D the smallest so that the trees of different sizes, in each treatment could be compared with trees of corresponding size in the other treatments.

Due to considerable variations in size and yield of individual trees even in the same group under different treatments, it was not possible to include all the trees in the experiment for the purpose of statistical interpretation of the results. The appendix gives mean yield of all the trees in each group under each treatment, which bears out in a general way the results obtained in the case of 24 uniform trees selected for statistical analysis of the results. Mean yields of all the trees under various treatments for a period of five years are given in Table IX, which shows that manured trees have invariably given higher yield than control, and further that 4 lb. dose per tree has also proved to be the best.

TABLE IX

Mean yields of all trees for a period of five years

Grade	Control	4 lb. dose	8 lb. dose	12 lb. dose
A	339	457	415	428
B	222	350	270	275
C	176	230	196	203
D	114	147	144	157

5. Relation of growth to productivity

From Table II (which contains mean girths of trees in 1933) and Table IV (which contains mean girths of trees from 1934 to 1938), percentage increase or decrease of girth over the control is recalculated and presented in Table XI. The method of calculation was to subtract the mean value of girth for a year from the mean girth of the following year for all the treatments. The differences thus obtained and given in Table X show the increase in girth of trees from year to year. From these differences (Table X), percentage increase or decrease in girth of the manured trees over the control were calculated.

TABLE X

Actual increase in the mean girths of trees over the preceding year from 1934 to 1938

Treatment	Increase in mean girths from				
	1933 to 1934	1934 to 1935	1935 to 1936	1936 to 1937	1937 to 1938
Control . .	2·4	1·9	1·1	1·2	0·8
4 lb. dose . .	2·8	1·4	1·8	1·8	1·5
8 lb. dose . .	3·0	1·3	1·4	1·6	1·5
12 lb. dose .	3·1	1·1	1·3	1·6	1·1

TABLE XI

Percentage increase or decrease in girths of manured trees over the control

Treatment	Percentage increase or decrease in girth				
	1934	1935	1936	1937	1938
4 lb. dose . .	+16·6	—26·3	+63·6	+50·0	+87·5
8 lb. dose . .	+25·0	—31·6	+27·2	+33·3	+87·5
12 lb. dose .	+29·1	—42·1	+18·2	+33·3	+37·5

If Table XI (girths) is compared with Table VIII (yields), it is quite clear that in 1934 the percentage increase in girth over the control was in order of the quantity of the fertilizer applied, i.e. 12 lb. dose gave the highest increase in girth and 4 lb. dose the least with 8 lb. dose falling between the two. Now looking at Table VIII it is evident that the position is reversed in case of percentage increase in yield, 4 lb. giving the highest increase and 12 lb. the least. During 1935 percentage decrease in girth occurred over the control, the amount of decrease being greater in higher doses. The yields, on the other hand, were higher in higher doses, showing an inverse relationship between growth and productivity during the same year. In the subsequent years also the same relation in general existed between growth and productivity, i.e. when the percentage increase in crop over the control was higher, the percentage increase in the girth was lower and *vice versa*, thus showing that fruiting and vegetative growth are always at the expense of each other, or that fruiting is a dwarfing process.

6. Relative economy of various doses

The mean yield per tree per season for the period under the experiment worked out to be 189, 243, 246 and, 257 fruits, respectively for control 4 lb., 8 lb. and 12 lb. doses, which shows an annual increase of 54, 57 and 68 fruits per tree of various doses over the control. Taking 109 trees per acre (the trees in the orchard are planted 20 ft. apart on square system) the increase in yield per acre over the control comes to 5886, 6213 and 7412 fruits respectively for trees treated with 4 lb., 8 lb., 12 lb. doses. The extra price realized per acre by the use of the fertilizer works out to be as follows. The actual prices of Malta oranges prevalent in the market as well as the price of the fertilizer during different years form the basis of calculation.

Price of Malta oranges	4 lb. dose	8 lb. dose	12 lb. dose
	Rs. A. P.	Rs. A. P.	Rs. A. P.
Price of Malta oranges produced in excess over control	114 0 7	120 6 0	143 9 8
Cost of the fertilizer . . .	24 15 0	49 14 0	74 13 0
Net income	89 1 7	70 8 0	68 12 8

It is clear from the above that the most profitable dose is the least dose, i.e. 4 lb.

Discussion

Local variety of sweet orange growing on rough lemon rootstock constituted the material used for these investigations. The stock portion of the plants being of seedling origin, no doubt, introduces an element of uncertainty with regard to the genetic constitution of the rootstock, but investigations in this line of research have not proved conclusively the advantages or disadvantages of clone and seedling roots over one another in producing uniform plants budded or grafted on them. Hatton [1931] reports that the trees on seedling rootstocks were more variable than those on clones with respect to girth and yield, while Roberts [1927, 1929] associates such variability with causes other than the constitution of rootstocks. That grading of rootstocks, whether clone or seedling, would ensure more uniform trees is accepted almost by every horticulturist. A rootstock may be raised by vegetative means and unless it is uniformly graded it would give rise to material more variable than seedling stocks properly graded. Anthony and Yerks [1928], comparing the growth made by trees on seedling rootstock with those on clone rootstock, state that more uniform sizing of the trees on commercial seedling roots continued to maintain higher degree of uniformity in the orhard. In the material under study though no grading of the rootstock was done prior to the insertion of buds or at the time when the trees were planted in the orchard, yet the method of grouping of trees at the outset of the experiment, where it was shown that the trees with respect

to growth and productivity were quite uniform and were growing on a uniform piece of land, coupled with the ability of rough lemon rootstock to produce 90-100 per cent apogamic seedlings [Marloth, 1938] amply justifies the suitability of the material for the investigation carried out and reported in this paper. Variant seedlings which were found by Webber [1932] to produce almost weak and dwarfed orchard trees, would undoubtedly be eliminated as a result of the method employed in the selection of the material.

In 1938, due to the presence of organic matter in the soil in the form of farmyard manure, 4-lb. treated trees gave increased girths over the control. But growth records of trees from 1934 to 1937, as manifested in their girth measurements, show that size of the trees under various treatments was not apparently affected—control and manured trees not showing any significant difference in their size. Increased yield obtained in the case of manured trees, therefore, cannot be attributed to bigger trees producing more potential bearing surface. While the bearing surface of the trees under various treatments remained the same, fruiting in the manured trees was increased, showing that nitrogen was a limiting factor in the setting and subsequent development of fruits in control trees. The importance of an adequate amount of nitrogen at the time of setting of fruit and its subsequent development has been emphasized by many. Hooker [1920], Harley [1925] and Schrader and Auchter [1925] report that fruiting spurs had a greater percentage of total nitrogen than non-fruiting spurs about the end of June. Determination of the nitrogen content of fruit of Eureka lemon, Washington Navel orange and Marsh grapefruit were made by Cameron and others [1936] at fortnightly intervals at Riverside California and also in the case of two oranges at Los Angeles. They have shown that the total nitrogen increased at approximately the same rate throughout the period of fruit development. Anderssen [1937] reports that application of nitrogenous fertilizer caused an increased crop, the increase in tree size did not exceed that of the control, but was rather the reverse.

The manured trees responded more in the way of giving higher yield in later years, especially in 1938. This in part may be due to steady depletion of nitrogen from the control plot year after year. But the highest percentage yield obtained during 1938 suggests that probably it was the lack of organic matter in the soil that was responsible for the fertilized trees not making use of inorganic supply of nitrogen to such an extent as they did when organic matter was applied in the form of farmyard manure. Even though adequate quantities of plant nutrients are present in a soil, these may not become available to the plants, due to lack of organic matter, in the absence of which soil organisms, making the nitrogenous plant food available from unavailable form, are altogether inadequate or inactive. Even unavailable forms of potash and phosphoric acid are not generally made available in the absence of organic matter. The lack of organic matter in control and treated plots was evident in 1937 when the trees began to develop mottle leaf. Vaile [1922, 1924] mentions that the use of nitrogen in the form of concentrated commercial fertilizer led to the development of mottle leaf and the trees became practically unproductive after a few years and bulky organic manure caused less mottling as compared to the concentrated nitrogenous manure. Chapman [1938] recommends the use of bulky organic material in citrus

orchards in California. In view of the results obtained from this experiment and the findings of others, it is suggested that along with inorganic nitrogenous concentrated fertilizers, an adequate amount of organic matter be added to the trees to obtain best results.

It has been shown that 8 or 12 lb. dose of the fertilizer did not give significantly increased yields over 4 lb. dose excepting in one season when 12 lb. dose gave significantly higher yield than 4 lb. dose. The most profitable dose under the conditions of the experiment was of 4 lb. and any increase of the fertilizer over this dose seems to be unnecessary as it did not affect either the size of crop or vigour of the trees. The same results were obtained by Anderssen [1937] who concludes that the application of ammonium sulphate to soil induced very marked increase in weight of crop and number of fruits and there was no significant difference in crop, however, between applications of 2, 4 and 6 lb. of ammonium sulphate per tree. It is proposed to lay out an experiment to determine the efficacy of still smaller dose of ammonium sulphate.

Summary and conclusions

1. The paper deals with the investigations carried out at Chak 45 G. B., Gojra, Lyallpur, from 1933 to 1938 on citrus manuring.

2. Yield records were kept for all the trees of common variety of Malta, which were nine years old, in various plots under different treatments numbering 111 under control, 120 under 4 lb. dose, 125 under 8 lb. dose and 145 under 12 lb. dose. Out of these, 24 trees were selected in 1932 under each of the four treatments and were grouped for their uniformity with regard to growth and productivity before any fertilizer was applied.

3. Three doses of ammonium sulphate, viz. 4 lb.,8 lb., and 12 lb., were applied annually per tree from 1933 to 1937 to the plots under the respective treatment. The fertilizer was applied half prior to blossoming, i.e. third week of February, and the remaining half in the middle of May. A fourth lot of trees was kept as control. In February 1937, a supplementary basal dressing of 60 lb. farmyard manure was applied per tree to all the four treatments including the control because of the appearance of mottle leaf.

4. Girth measurements and yield records were taken each year from the inception to the conclusion of the experiment.

5. The data with respect to growth and productivity of 24 grouped trees were examined statistically.

6. In the absence of an adequate amount of organic matter in the soil application of various doses of the fertilizer did not affect the size of trees. Control and treated trees did not exhibit any significant difference in their size.

7. In the presence of farmyard manure in the soil, 4-lb. treated trees grew bigger in size than the untreated ones.

8. Manured trees gave increased yield over control.

9. There was no significant difference in the number of fruits produced on trees receiving different doses of the fertilizer, i.e. 4, 8 and 12 lb. per tree.

10. The lack of organic matter in the soil caused mottle leaf.

11. Fertilizer in conjunction with farmyard manure gave increased yield over the fertilizer alone.

12. Fruiting dwarfed the trees in proportion to the amount of crop borne.

Acknowledgements

The authors are indebted to Mr. Sangat Singh and Mr. Abdur Rashid Khan for collecting a part of the data.

References

Allwright, W. J. (1937). *Western Transvaal Publication (mimeographed) S. Afr. Coop Citrus Exchange*

Anderssen, F. G. (1937). *J. Pom. & Hort. Sci.* **15**, 117-59

Anthony, R. D. and Yerks, G. E. (1928). *Proc. Amer. Soc. Hort. Sci.* **69**

Batchelor, L. D.; Parker, E. R. and McBride Robert (1928). *Calif. Agric. Expt. Sta. Bull.* **451**

Booth, C. T. (1928). *Cheffy Fertilizer Expt. Ann. Rept.* **12**, 7

C. S. I. R. Aust. (1934-35). *Griffith Citri Res. Sta. Ann. Rept.*, p. 8

Cameron, S. H. and others (1935-36). *Proc. Amer. Soc. Hort. Sci.* **33**, 87-9

Chapman, H. D. (1934). *Calif. Agric. Exp. Sta. Bull.* **571**

——— (1938). *Calif. Citrogr.* **23**

Fisher, R. A. (1932). *Statistical methods for research workers* (Fourth edn.) : Oliver and Boyd, Edinburgh

Harley, C. P. (1925). *Proc. Amer. Soc. Hort. Sci.* **22**

Hatton, R. G. (1928-30). *Ann. Rept. East Mall. Res. Sta. II Supplement*, pp. 13-21

Hooker, H. D., Jr. (1920). *Mo. Agric. Expt. Sta. Res. Bull.* **40**

Kinman, C. F. (1915). *P. R. Dept. Agric. Bull.* **18**

Lander, P. E., Ramji Narain and Mehta, M. L. (1929). *Mem. Dept. Agric. India (Chem. Ser.)* **10**, No. 2

Lyon, T. L. and Heinicke, A. J. (1923). *Cornell Agric. Expt. Sta. Memoirs* **63**

Morloth, R. H. (1938). *Dept. Agric. and Forestry, Union South Africa, Reprint No.* **50**

Morris, A. A. (1936). *Ann. Rept. Mazoe Citrus Exp. Sta., 1936*

Murneek, A.E. (1928). *Mo. Agric. Expt. Sta. Res. Bull.* **119**

Potter, G. F. (1927). *Proc. Amer. Soc. Hort. Sci.* **24**, 234-6

Roberts, R. H. (1927). *Wis. Agric. Expt. Sta. Res. Bull.* **77**

——— (1929). *Wis. Agric. Expt. Sta. Res. Bull.* **94**

Schrader, A. L. and Auchter, E. C. (1925). *Proc. Amer. Soc. Hort. Sci.* 150-60

Vaile, R. S. (1922). *Univ. Calif. Agric. Exp. Sta. Bull.* **345**

——— (1924). *Calif. Agric. Expt. Sta. Bull.* **374**

Webber, H. J. (1932). *Hilgardia* **7**, 1-79

APPENDIX

Mean yield (number of fruits) per tree of all the grades of trees under different treatments 1934-38*

Grades of trees	A				B				C				D			
Treatments	Control	4 lb, dose	8 lb. dose	12 lb. dose	Control	4 lb. dose	8 lb. dose	12 lb. dose	Control	4 lb. dose	8 lb. dose	12 lb. dose	Control	4 lb. dose	8 lb. dose	12 lb. dose
1934 . .	376	548	562	587	276	413	371	364	224	316	279	242	127	170	156	163
1935 . .	512	629	600	520	335	481	371	373	280	289	254	303	170	195	252	249
1936 . .	409	462	420	435	281	393	290	287	215	237	216	205	137	157	141	139
1937 . .	203	248	192	211	108	165	98	142	85	111	82	93	64	77	67	87
1938 . .	194	397	303	386	112	299	221	212	75	198	152	175	72	137	104	146
Total .	1,694	2,284	2,077	2,139	1,112	1,751	1,351	1,378	879	1,151	983	1,018	570	736	720	784
Mean .	339	457	415	428	222	350	270	275	176	230	196	203	114	147	144	157

*Total number of trees under experiment being 501, i.e. 111 under control, 120 under 4 lb. dose, 125 under 8 lb. dose and 145 under 12 lb. dose

A KEY FOR THE IDENTIFICATION OF THE LARVAE OF THE KNOWN LEPIDOPTEROUS BORERS OF SUGARCANE IN INDIA BASED ON MORPHOLOGICAL CHARACTERS

BY

P. V. ISAAC, B.A., M.Sc., D.I.C., I.A.S.
Second Entomologist (Dipterist)

AND

K. V. RAO, B.Sc., Assoc. I.A.R.I.
Anatomical Assistant

Scheme for Research on Insect Pests of Sugarcane, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 5 April 1941)

(With Plates XLI—XLV)

THE following is an account of the study of the external morphology of the larvæ of the common caterpillar borers in sugarcane in India carried out with a view to preparing a key for their identification in the larval stage.

A classification of the borers of sugarcane, rice, etc. was published by Fletcher and Ghosh [1919], Ghosh [1921] and Fletcher [1927] based on body colour and stripes and differentiating morphological characters. The first-named two publications give details of life-history, seasonal history and alternative host plants. A recent paper by Gupta [1940] has dealt with the anatomy, life and seasonal history of four species of striped moth borers in northern Bihar and western United Provinces. The setal arrangement and the external morphological characters of the larvæ are described and utilized for their differentiation.

This paper deals with an alternative classification of the common caterpillar borers of only sugarcane based mainly on a study of the setal characters, some other morphological characters being also taken into consideration for purposes of differentiation.

The study of Lepidopterous larvæ in general made by Dyar [1893-95 ; 1910], Forbes [1910], Fracker [1915], etc. in America has led to the conclusion that certain of the setae (primary and sub-primary) borne by the caterpillars on their body segments are always constant and their variation in position and number afford valuable characters for classification. Classifications of the Lepidopterous larvæ in general based on the setal arrangement have been published by the above-named authors.

For a proper understanding of the positions normally occupied by the setae, it is necessary to examine a typical segment. A segment may contain three kinds of setæ, namely, (1) primary, which are found in the first instar and are

constant throughout the larval life, (2) sub-primary, which appear after the first moult of the larva and are fairly constant throughout all the succeeding instars and (3) secondary, which appear in later instars, are not constant, do not assume definite positions and bear no relation to the primary setæ.

The maximum number of primary and sub-primary setæ that can appear in any of the segments, according to Fracker [1915], is about 15. All these setæ are rarely borne by any one species, as variations and reductions are common. A hypothetical segment bearing all these setæ in their normal positions named after Greek letters by Fracker would be as shown in Plate XLI, fig. 1 (the area covered by the rectangle represents the area between the mid-dorsal and mid-ventral line of a segment on one side and the positions of all setæ correspond to their natural positions on the segment) :—

There are six setæ abcve the spiracle, in two vertical rows of three setæ each, the cephalic row consisting of alpha, gamma, and epsilon, the caudal row consisting of beta, delta and rho. At the level of the spiracle is theta. Just below the spiracle, are two setæ, kappa and eta. At the outer base on the leg, two setæ pi and nu, and the inner base of the leg near the mid-ventral line, sigma, tau and omega. Between kappa and pi towards the caudal border of the segment, one seta, mu. Among these, except theta and mu which are sub-primary, all setæ are primary.

Some of the setæ mentioned above are always found in association with one another and hence are designated as a group bearing the name of one of the setæ of the group as for instance, ' kappa ' group represents kappa and eta, ' pi ' group represents pi and nu.

The system adopted by Dyar and followed by Forbes and others consists in giving Roman numerals to the setae starting from the mid-dorsal line downwards. According to Dyar [1893-95] there are two types of arrangement :— ' The first, which is by far the most generalized, consists (considering only the abdominal segments) of five tubercles above the spiracle on each side, three in a transverse row about the middle of the segment and two behind ; below the spiracle are two oblique rows containing, respectively, two and four tubercles. This type is found in Hepialus and is probably typical of the moths in Prof. Comstock's first sub-order, the Jugatæ.

The second type contains two dissimilar lines of modifications of the first type ; but as they agree in number of the tubercles and in other characters they are considered together. The fundamental arrangement of the tubercles is as follows :—on each side above the spiracle three tubercles ; below or behind the spiracle and above the base of the leg, three more ; on the base of the leg three (or four) on the outside and one on the inside near the mid-ventral line. These are designated thus counting from the dorsal line :— Tubercles I, II, III, above the spiracle ; IV, V, VI, below ; the group of three on the outside of the leg as VII and the single one on the inside of the leg as VIII. Tubercles VII and VIII are present also on the legless abdominal segmengs in the corresponding position '.

In this nomenclature certain minute setæ which are very inconspicuous, save in a few cases, have not been included. Forbes [1921] calls these the small primaries and has designated them thus :—

IIIa—a small seta found near Tubercle III.

Xa, Xb, Xc, Xd—variable number of small setæ found between tubercles I and III.

IXa, IXb—variable number of small setæ found cephalad of the base of leg (Fracker, however has included all these setæ in his nomenclature and the corresponding names are as follows) :—

IIIa—epsilon,

Xa, Xb, Xc, Xd—gamma,

IXa, IXb—omega, phi.

A typical segment (abdominal) bearing all the setae enumerated above will therefore be as shown in Plate XLI, fig. 2.

The homology between Fracker's nomenclature and that of Dyar will therefore be as follows :—

Fracker	Forbes (after Dyar)—(abdomen)*	
	Frenatæ	Jugatæ
alpha	I	I
beta	II	II
gamma	X	X
delta	Absent	Absent
epsilon	IIIa	IIIa
rho	III	III
theta	Absent	IV
kappa	IV	V
eta	V	VI
mu	VI	Absent
pi	VIIa	VIIa
nu	VIIb	VIIb
sigma	VIII	VIII
omega	IXa	IXa
phi	IXb	IXb

* Here the comparison is shown only between abdominal setæ because in this paper only the abdominal setae have been utilized for the purposes of differentiation.

The borers the differentiation of which is set out in this paper are the common pests of sugarcane in India. They are 12 species belonging to three families and five sub-families, as follows :—

Name of species	Habit	Family	Sub-family
1. *Scirpophaga nivella* F.	Top shoot borer	Pyralidæ	Schoenobiinæ
2. *Argyria sticticraspis* Hmpsn.	Stem borers	Pyralidae	Crambinæ
3. *Argyria tumidicostalis* Hmpsn.			
4. *Diatraea auricilia* Dudgn.			
5. *Diatraea venosata* Wlk.			
6. *Chilo zonellus* Swinh.			
7. *Chilo trypetes* Bisset			
8. *Raphimetopus ablutella* Zell.	Stem borer	Pyralidae	Anerastinæ
9. *Emmalocera depressella* Swinh.	Root borer	Pyralidae	Anerastinæ
10. *Sesamia inferens* Wlk.	Stem borer	Noctuidæ	Acronyctinæ
11. *Sesamia uniformis* Dudgn.	Stem borer	Noctuidæ	Acronyctinæ
12. *Procometis trochala* Meyr.	Stem borer	Cryptophasidæ	

Method of study and characters employed

Full-grown or nearly full-grown larvæ of the 12 species mentioned above were used for the study. At least 12 specimens of each species were examined. Permanent mounts of the head capsule and entire skin were made in Canada balsam on slides for examination under microscope.

For the study of the chætotaxy of the body segments diagrammatic sketches were drawn in the standard way followed by Fracker, Forbes, etc., i.e. the area covered between the mid-dorsal line and mid-ventral line in a segment on one side being represented as a rectangle and the setae within this area plotted in their corresponding places.

Examination of the setal plans of the head capsule and thoracic and abdominal segments of the mature larvæ of the 12 species of borers has revealed certain striking differences in the setal arrangement of the abdominal segments which divide the 12 species primarily into certain groups. The characters that have been found to be of use in this classification are the total number of setae (on one side) in the ninth abdominal segment (excluding the small primaries), the number of setae in the ' pi ' group of Fracker or seta VII of Forbes, in the first, third and seventh abdominal segments. Further division of these groups is based on the arrangement of the crochets on the abdominal (first four) prolegs, the nature and shape of the spiracles, and the position

of the trapezoidal tubercles (the chitinized portion around the base of the seta) on the abdomen. It will also be seen that the characters used are easily perceived and the differences enumerated are such as are easily noticed and understood.

A general description of the full-grown larvae of the 12 species of borers in sugarcane is given below :—

Scirpophaga nivella F.

Length 25-35 mm. Breadth at the thickest portion 3-4 mm. Caterpillar cylindrical or slightly flattened dorso-ventrally, thickset or slender, tapering towards the anterior end and blunt towards the posterior. Skin smooth and not well chitinized. Setae small and indistinct. Head small, yellowish brown in colour, mandibles with five teeth, lower ones being pointed. Prothoracic shield not well developed, very light brown in colour. General colour of the thoracic and abdominal segments dirty yellowish white. Dorsal vessel prominently seen through the skin. Spiracles indistinct, elongated vertically, looking like yellowish brown streaks. Crochets on abdominal prolegs uniordinal, arranged in an oval outline.

Argyria sticticraspis Hmpsn.

Length about 25 mm. Breadth at the thickest portion about 3 mm. Caterpillar shows variability in shape, sometimes thickset and sometimes slender, cylindrical generally, sometimes slightly flattened dorso-ventrally. Skin well chitinized, setae stout and well developed. Head prominent, dark brown in colour, mandibles with six teeth rather rounded and blunt. Prothoracic shield well developed, dark blackish brown in colour. Mesothoracic plate is also prominent. Tubercles well developed. Five longitudinal stripes are present on the abdomen, one mid-dorsal, two sub-dorsals and two laterals. The stripes are usually light pinkish brown in colour, sometimes darker. On the abdominal segments, the posterior trapezoidal tubercles more lateral in position than the anterior trapezoidal tubercles. Spiracles open (i.e. there is a clear space inside), elongate oval, with black rims, situated well below the lateral stripes. Crochets on abdominal prolegs multiordinal and arranged in incomplete circles (about three-fourths complete).

Argyria tumidicostalis Hmpsn.

Length about 30 mm. Breadth at the thickest part about 3·5 mm. Caterpillar thickset, slightly blunt at both ends. Skin well chitinized and the setae are short and prominent. Head prominent, dark brown, mandibles with six teeth rather blunt in shape. Prothoracic shield well developed, dark brown in colour. Tubercles on the thoracic and abdominal segments well developed. The posterior trapezoidal tubercles on the abdomen almost in a line with the anterior trapezoidal tubercles. Four longitudinal stripes present on the abdomen, two sub-dorsal and two lateral. Fletcher and Ghosh [1919] record that the markings on the body show the following variations : (1) There may be two broad, slightly pinkish brown stripes on each side of the body, one subdorsal and the other supra-spiracular, (2) the stripes may be indistinct, the tubercles only being prominent on the skin, (3) the tubercles may be indistinct, stripes only being present in an interrupted manner and the two stripes

on each side approaching each other at intervals, (4) both stripes and tubercles may be indistinct. Spiracles open (i.e. there is a clear cavity inside), elongate oval, and situated just beneath the lateral stripe. Crochets on the abdominal prolegs multiordinal and form complete circles.

Diatraea auricilia Dudgn.

Length about 25 mm. Breadth at the thickest portion about 2·5 mm. Caterpillar slender, cylindrical, tapering. Skin well chitinized, setae well developed. Head prominent, reddish brown in colour, mandibles with six teeth rather blunt. Prothoracic shield well developed, dull yellowish brown in colour. Tubercles on the thoracic and abdominal segments not well developed. The posterior trapezoidal tubercles on the abdomen more lateral in position than the anterior trapezoidal tubercles. Five longitudinal stripes present on the abdomen, one mid-dorsal, two sub-dorsals, and two laterals. Stripes are reddish brown in colour. Sub-dorsals most prominent, laterals indistinct. Spiracles open (i.e. there is a clear space inside), elongate oval, situated below the lateral stripe. Crochets on the abdominal prolegs multiordinal, and arranged in complete circles.

Diatraea venosata Wlk.

Length about 35 mm. Breadth at the thickest portion about 4 mm. Caterpillar thickset, slightly tapering posteriorly. Skin well chitinized, setae stout and well developed. Head prominent, shiny yellowish brown in colour, mandibles with six teeth, lower ones being pointed. Prothoracic shield well developed, yellowish brown in colour. Tubercles on the thoracic and abdominal segments well developed and are seen as dark bluish black patches on the skin. Four longitudinal stripes present on the abdomen, two sub-dorsals and two laterals. The colour of the stripes pinkish brown. Fletcher and Ghosh [1919] record that in some cases the stripes may be indistinct and in certain other cases again the tubercles may be indistinct. In hibernating larvae both the stripes and tubercles may be indistinct. The anterior and posterior trapezoidal tubercles on the abdominal segments are almost in a line and are situated along the sub-dorsal stripe. Spiracles closed (i.e. there is no clear space inside), broad oval in shape, with blackish rims, and situated along the lower margin of the lateral stripe. Crochets on the abdominal prolegs multiordinal and arranged in complete circles.

Chilo trypetes Bisset.

Length about 35 mm. Breadth at the thickest portion about 3 mm. Caterpillar slender, slightly flattened dorso-ventrally, tapering at both ends. Skin well chitinized and the setae are stout and well developed. Head prominent, light brown in colour, mandibles with six teeth, lower ones being sharply pointed. Prothoracic shield well developed, light brown in colour with patches of dark brown. Four longitudinal stripes are present on the abdomen, two sub-dorsal and two lateral. The sub-dorsal stripes are narrow and light pinkish brown in colour. The lateral ones are broader, very prominent and dark pinkish brown in colour. Spiracles are elongate, bean shaped and lie along the lateral stripe. Crochets on prolegs uniordinal and arranged in slightly more than semicircles.

Chilo zonellus Swinh.

Length about 25 mm. Breadth at the thickest portion about 3 mm. Caterpillar thickset, cylindrical. Skin well chitinized, setae well developed. Head prominent, reddish brown in colour, mandibles with six teeth, lower three being pointed. Prothoracic shield well chitinized and prominent, yellowish brown in colour. Four longitudinal stripes on the abdomen present, two sub-dorsal and two lateral. The stripes are reddish brown in colour. Fletcher and Ghosh [1919] record that the appearance of the caterpillars varies. The common form possesses distinct sub-dorsal brown stripes with tubercles indistinct. In a second form, the sub-dorsal stripes approach one another on the back and practically meet. In a third form, the stripes are rather distinct and tubercles prominent. The posterior trapezoidal tubercles are slightly more lateral in position than the anterior trapezoidal tubercles. Spiracles closed (no clear space inside), elongate oval, and lie along the lower margin of the lateral stripes. Crochets on abdominal prolegs are multiordinal and arranged in complete circles.

Raphimetopus ablutella Zell.

Length about 20 mm. Breadth at the thickest portion about 2·5 mm. Caterpillar thickset, slightly dorso-ventrally compressed. Skin well chitinized, setae slender and very long. Head not very prominent, reddish brown in colour, mandibles with only three lower teeth distinct, which are pointed. Prothoracic shield well developed, greenish in colour. Colour of the other segments of a uniform bluish green, sometimes copperish. Spiracles broad oval in shape with brownish rims. Crochets on abdominal prolegs biordinal and arranged in complete ovals.

Sesamia inferens Wlk.

Length about 30 mm. Breadth at the thickest portion about 3·5 mm. Caterpillar thickset, cylindrical, tapering posteriorly. Skin well chitinized and setae well developed. Head prominent, reddish brown in colour, mandibles with five teeth, lower three being long and pointed. Prothoracic shield well developed, yellowish brown in colour. Colour of the body segments a uniform pink, lighter on the ventral side. Spiracles elongate oval with black rims. Crochets on prolegs uniordinal and arranged in semicircles.

Sesamia uniformis Dudgn.

The description is more or less the same as for *Sesamia inferens* Wlk. (The two species of *Sesamia* could be distinguished in the pupal stage by morphological characters).

Procometis trochala Meyr.

Length about 24 mm. Breadth at the thickest portion about 2 mm. Caterpillar slender, cylindrical, slightly tapering posteriorly. Skin well chitinized and setae well developed. Head prominent, reddish brown in colour, teeth of mandibles undifferentiated. Prothoracic shield well developed, light brown in colour. A number of longitudinal stripes arranged closely on the abdomen, and not very distinct from each other. As many as four can be counted on

each side of the mid-dorsal stripe. The stripes are brownish in colour. Spiracles elongate oval, with dark brown rims. Crochets on abdominal prolegs multiordinal and arranged in complete ovals.

Emmalocera depressella Swinh.

Length about 25 mm. Breadth at the thickest portion about 2·5 mm. Caterpillar thickset, cylindrical, slightly tapering posteriorly. Skin well chitinized and setae well developed. Head prominent, yellowish brown in colour, mandibles with only the lower three teeth distinct. Prothoracic shield fairly well developed, light yellowish in colour. Colour of the body segments creamy white without any stripes. Dorsal vessel prominent in some cases. Spiracles rounded oval in shape. Crochets on abdominal prolegs biordinal and arranged in a pear-shaped outline.

Key for the larvae

(Reference Plates XLII—XLV)

Based on the characters mentioned in the text, the classification of the 12 species of borers is as follows :—

1. Ninth abdominal segment : total number of setae on one side, i.e. between mid-dorsal and mid-ventral line, six (excluding small primaries)	2
Ninth abdominal segment : total number of setae on one side, i.e. between mid-dorsal and mid-ventral line, eight (excluding small primaries)	8
2. First abdominal segment : seta VII of Forbes or pi group of Fracker consists of two setae. Crochets on abdominal prolegs : arranged in uni-ordinal series	3
First abdominal segment : seta VII of Forbes or pi group of Fracker consists of three setae. Crochets on abdominal prolegs : arranged in multi-ordinal series . . .	4
3. Seventh abdominal segment : seta VII of Forbes or pi group of Fracker consists of one seta. Crochets on prolegs : arranged in semicircles	*Sesamia inferens* Wlk. *Sesamia uniformis* Dudgn.
Seventh abdominal segment : seta VII of Forbes or pi group of Fracker consists of two setae. Crochets on prolegs : arranged in slightly more than semicircles . .	*Chilo trypetes* Bisset
Seventh abdominal segment : seta VII of Forbes or pi group of Fracker consists of three setae. Crochets on prolegs : arranged in complete ovals	*Scirpophaga nivella* F.
4. Crochets on abdominal prolegs : arranged in incomplete circles	*Argyria sticticraspis* Hmpsn.
Crochets on abdominal prolegs : arranged in complete circles	5
5. Spiracles : open (i.e. there is a clear space inside) . .	6
Spiracles : closed (i.e. there is no clear space inside) .	7
6. Trapezoidal tubercles on the abdomen : anterior and posterior tubercles in a line	*Argyria tumidicostalis* Hmpsn.
Trapezoidal tubercles on the abdomen : posterior tubercles more lateral than anterior tubercles . . .	*Diatraea auricilia* Dudgn.

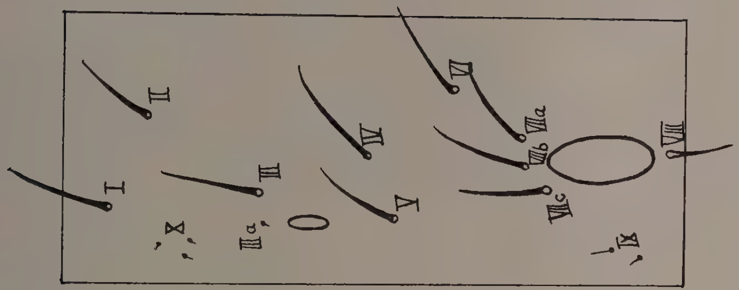


FIG. 2. A typical segment (abdominal) bearing setae

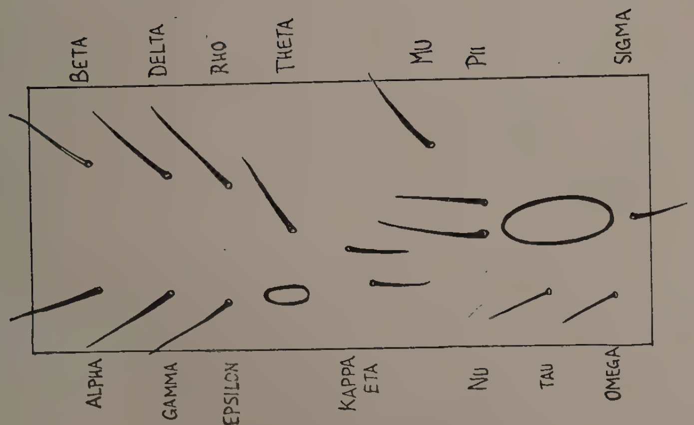
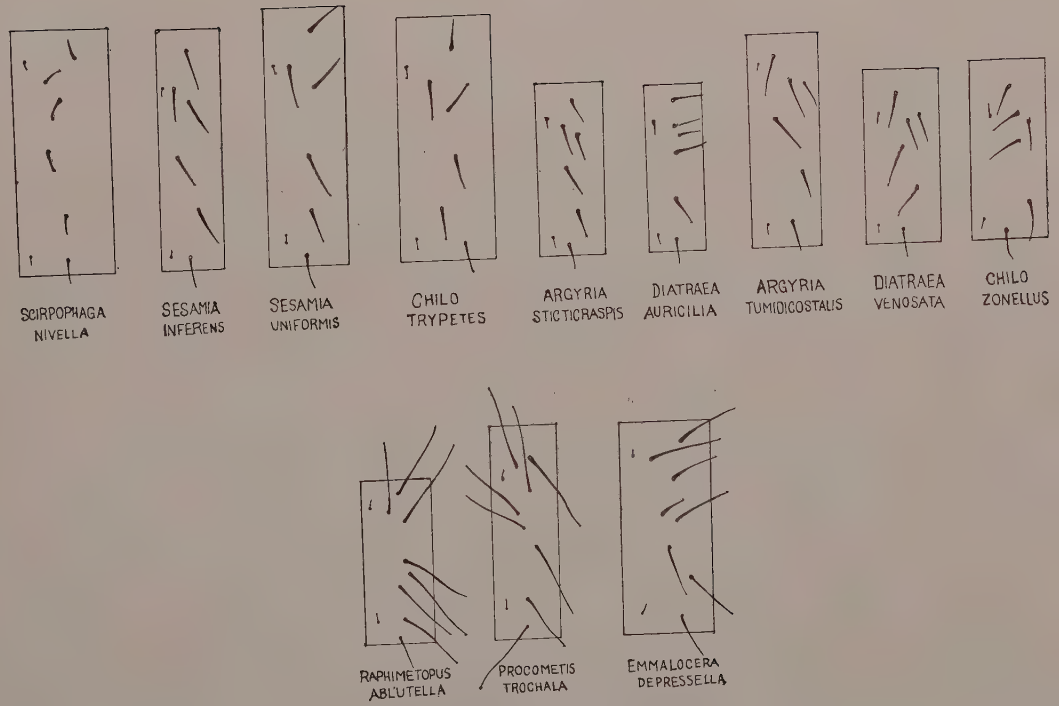
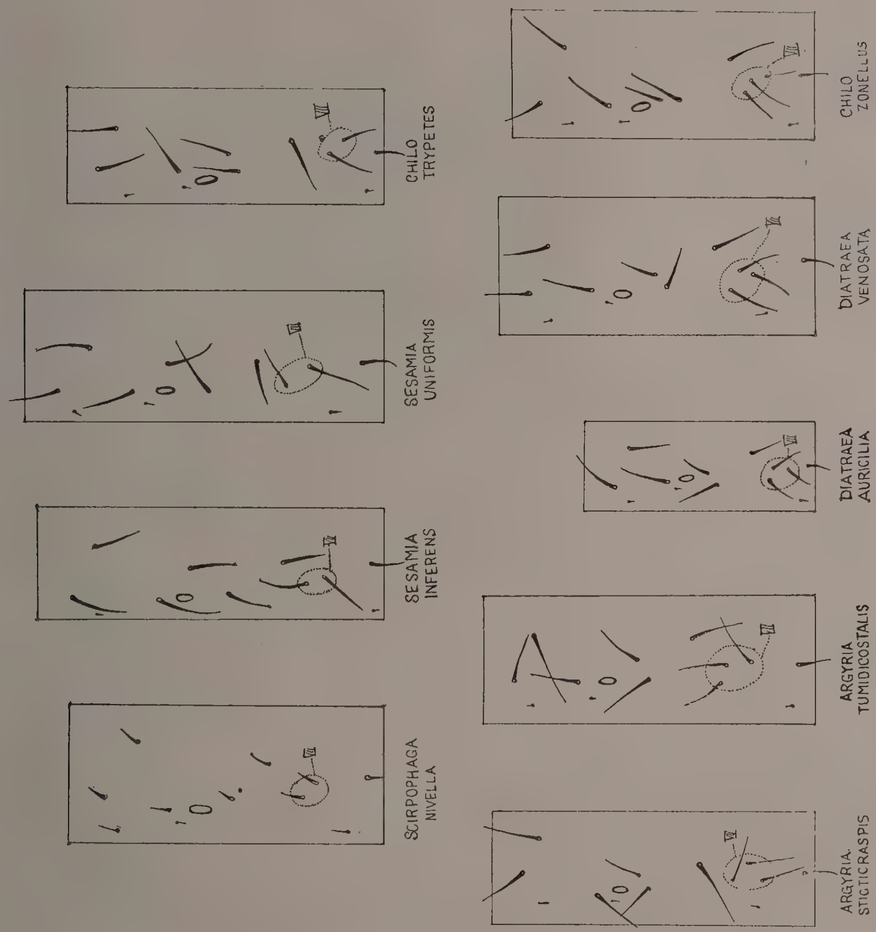


FIG. 1. A hypothetical segment bearing setae in their normal positions

[*Indian J. agric. Sci.*, Vol. 11 Part V



Ninth abdominal segment : setal arrangement (×12)



First abdominal segment : setal arrangement (×12)

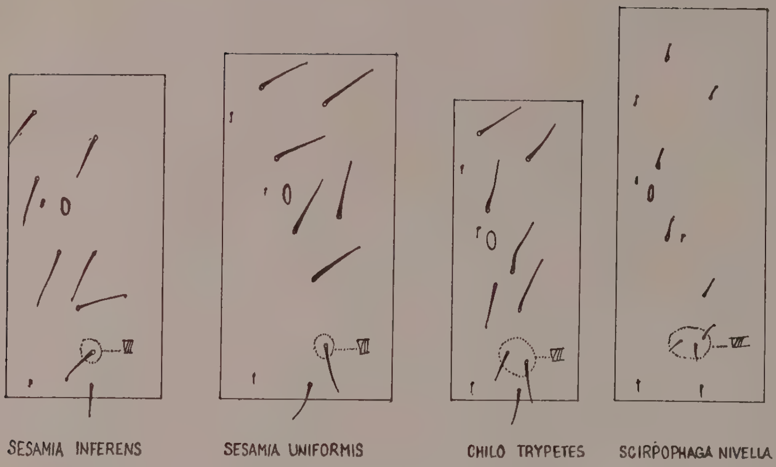


FIG. 1. Seventh abdominal segment : setal arrangement (×12)

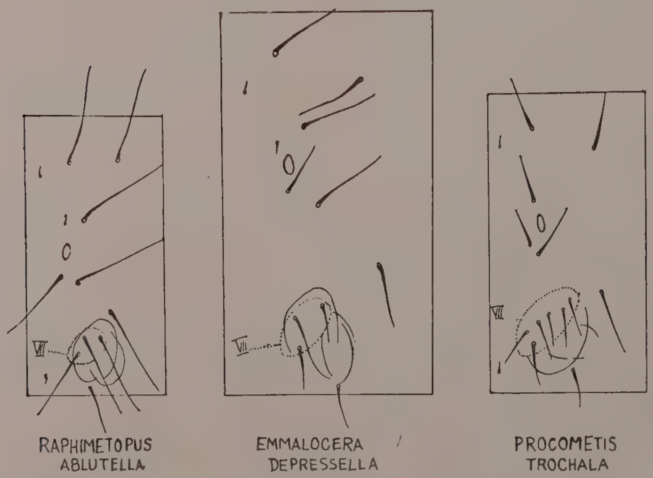
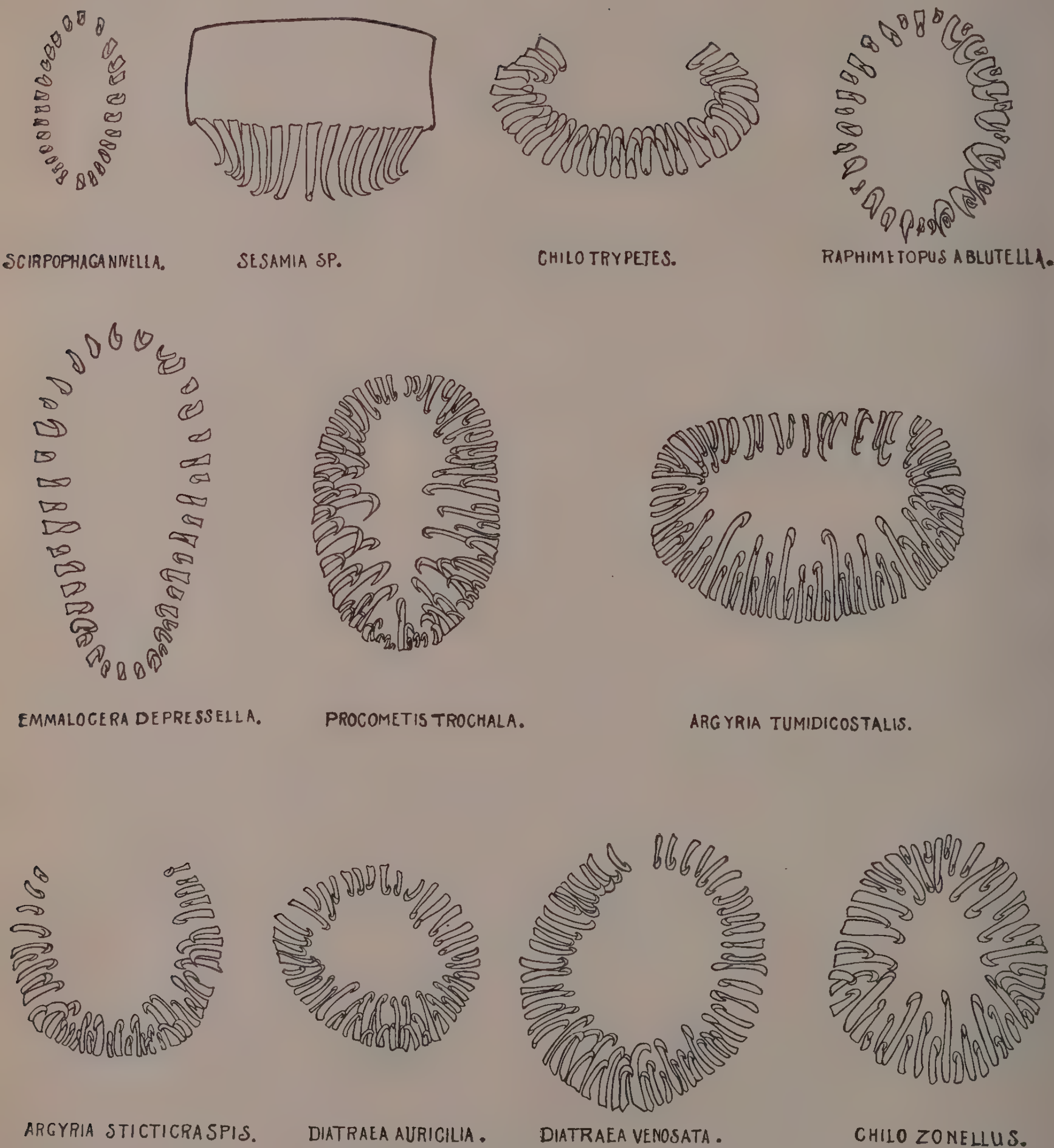


FIG. 2. Third abdominal segment : setal arrangement (×12)

[*Indian J. agric. Sci.*, Vol. 11, Part V



Crochets on abdominal prolegs (×80)

7. Spiracles : slightly elongate oval in shape . . .	*Chilo zonellus* Swinh.
Spiracles : broad oval to round in shape . . .	*Diatraea venosuta* Wlk.
8. Third abdominal segment : seta VII of Forbes or pi group of Fracker consists of five or six setae	*Procometis trochala* Meyr.
Third abdominal segment : seta VII of Forbes or pi group of Fracker consists of only three setae	9
9. Crochets on abdominal prolegs : arranged in a broad oval outline	*Raphimetopus ablutella* Zell.
Crochets on abdominal prolegs : arranged in a pear-shaped outline	*Emmalocera depressella* Swinh.

Acknowledgements

This work was done under the scheme for research on Insect Pests of Sugarcane at the Imperial Agricultural Research Institute, New Delhi, financed by the Imperial Council of Agricultural Research.

REFERENCES

Dyar, H. G. (1893-95). *Ann. N. Y. Acad. Sci.* **8**, 194-232

——— (1901). *Ent. Rec.* **13**, 37-41

Fletcher, T. B. (1927). *Ann. Rept. Impl. Entomologist, Pusa, 1926-27*, pp. 56-67

Fletcher, T. B. and Ghosh, C. C. (1919). *Rept. Proc. Third Entomological Meeting, Pusa*, pp. 368-9 (Also published as *Bulletin No.* **102**, *Agric. Res. Inst., Pusa*)

Forbes, W. T. M. (1910). *Ann. Ent. Soc. Amer.* **3**, 94-132

——— (1916). *J. N. Y. Ent. Soc.* **24**, 137-42

——— (1921). *Ann. Ent. Soc. Amer.* **14**, 344

Fracker, S. B. (1915). *Illinois Biol. Monogr.* **2**, part 2, pp. 1-169 [Also second Edition, revised and reprinted, 1930 (*Contributions from the Ent. Laboratories of the University of Illinois, No.* **43**)]

Ghosh, C. C. (1921). *Rept. Proc. Fourth Entomological Meeting, Pusa* p. 114 (Also published as *Bulletin No.* **134**, *Agric. Res. Inst., Pusa*)

Gupta, B. D. (1940). *Indian J. agric. Sci.* **10**, 781-817

A KEY FOR THE IDENTIFICATION OF THE PUPAE OF THE KNOWN LEPIDOPTEROUS BORERS OF SUGARCANE IN INDIA, BASED ON MORPHOLOGICAL CHARACTERS

BY

P. V. ISAAC, B.A., M.Sc., D.I.C., I.A.S.

Second Entomologist (Dipterist)

abstr. by C.D.F.

AND

T. V. VENKATRAMAN, B.A., M.Sc.

Anatomical Assistant

Scheme for Research on Insect Pests of Sugarcane, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 5 April 1941)

(With Plates XLVI-L)

SCUDDER [1889] was the first to attempt a classification of the Lepidoptera based on pupal characters. His classification was based on the various projections from the body, the cuticular appendages, the colouration and the mode of suspension of the pupa. Chapman [1893-96] and Packard [1895] have made extensive studies on lepidopterous pupae. The most comprehensive work on pupal morphology was published by Mosher [1916, 1917]. She has drawn a classification of the Lepidoptera based on morphological characters of the pupae and has given correct homologies of the different parts of the pupa. Fletcher and Ghosh [1919] and Ghosh [1921] have given keys for the differentiation of pupae of the important borers in sugarcane, rice, etc. in India. Recently, Gupta [1940] has made a study of the anatomy of the different stages of four of the striped borers of sugarcane in India. The following is an attempt to present detailed descriptions of the pupae of all the common caterpillar borers of sugarcane, together with a key for differentiating them in their pupal stage.

Pupal morphology

All the pupae described here belong to the type known as 'obtected pupa', because all the appendages are firmly soldered to the body wall and have no power of independent movement. They are smooth and rounded and exhibit a hard exterior. The only free segments in both sexes are the fourth, fifth and sixth. A short cremaster (prolongation of the anal segment carrying spines) is generally present. In the case of *Scirpophaga nivella* Fabr. it cannot be called an obtected pupa in the real sense, because all the appendages are not completely soldered to the body wall, the tips being free. A cremaster is absent and the various parts of the body are very lightly chitinized. But as in obtected pupa, *Scirpophaga nivella* has got only the fourth, fifth and sixth abdominal segments free. In *Emmalocera depressella*

SIDEVIEW OF FEMALE PUPAE OF DIFFERENT BORERS (×3)

1. *Scirpophaga nivella* Fabr. ; 2. *Argyria sticticraspis* Hamps. ; 3. *Argyria tumidicostalis* Hamps. ; 4. *Diatraea auricilia* Dudgn. ; 5. *Diatraea venosata* Walk. ; 6. *Chilo trypetes* Bisset ; 7. *Chilo zonellus* Swinh. ; 8. *Emmalocera depressella* Swinh. ; 9. *Sesamia uniformis* Dudgn. ; 10. *Sesamia inferens* Walk. ; 11. *Raphimetopus ablutella* Zell. ; 12. *Procometis trochala* Meyr.

Swinh., the cremaster is very poorly developed and is reduced to a chitinized transverse ridge on the dorsum of the anal segment. The pupae of the striped borers are characterized by the peculiar form of the short, blunt cremaster and the deep lateral grooves on the tenth segment. The pupa of *Chilo trypetes* Bisset differs from those of the allied striped borers in certain morphological characters. A hypothetical pupa is drawn in Plate XLVII, figs. 1 and 2 to show the different parts of the pupa.

The following is the list of caterpillar borers studied, given under each family and sub-family :—

Name	Family	Sub-family
1. *Scirpophaga nivella* Fabr. . . .	Pyralidae	Schoenobiinae
2. *Argyria sticticraspis* Hmpsn. . . .	,,	Crambinae
3. *Argyria tumidicostalis* Hmpsn. . .	,,	,,
4. *Diatraea auricilia* Dudgn. . . .	,,	,,
5. *Diatraea venosata* Walk. . . .	,,	,,
6. *Chilo trypetes* Bisset	,,	,,
7. *Chilo zonellus* Swinh.	,,	,,
8. *Emmalocera depressella* Swinh. . .	,,	Anerastinae
9. *Sesamia uniformis* Dudgn. . . .	Noctuidae	Acronyctinae
10. *Sesamia inferens* Wlk.	,,	,,
11. *Raphimetopus ablutella* Zell. . . .	Pyralidae	Anerastinae
12. *Procometis trochala* Meyr. . . .	Cryptophasidae	

1. Scirpophaga nivella Fabr.

(Plate XLVI, fig. 1 ; Plate XLVII, figs. 3-5)

Pupa appears very delicate and with a soft exterior. Head and maxillae greyish and the rest of the body yellowish-white in colour. Eyepieces are bluish in advanced pupa. Head and appendages are enclosed in a transparent envelope and loosely soldered to the body ; the tips of wings and appendages stand out of the body. Vertex is indicated as a narrow strip and the epicranial suture is fairly distinct. Front is fairly well developed, shining, and more or less flat from above. Clypeus is bulged and rounded. Frontoclypeal suture is indistinct. Labrum is reduced to a small triangular piece and separated from the clypeus. Labial palpi is also very much reduced and indicated as a small piece just above the maxillae. Maxilla very short and is less than one-fifth the length of the wings. Glazed eyepiece is very much narrower than sculptured eyepiece. Genae are prominent and arched. Maxillary palpi are not indicated. Prothoracic legs half as long as the wings. Prothoracic legs extend a trifle between the sculptured eyepieces and antennae. A large portion of femur of the prothoracic leg is exposed. A small portion of femur of the metathoracic leg is also indicated. Mesothoracic spiracles are slit-like and inconspicuous. Mesothoracic legs five-sixths the length of the wings. Metathoracic legs extend beyond the wings and reach almost the caudal margin of the fifth abdominal segment. Abdominal spiracles produced and with slit-like opening and brownish edge. Abdominal segments soft, smooth and without any sculpturings, distinct spines or ridges

Anal end is rounded and a cremaster is absent. In advanced female pupa the pinkish or yellowish anal tuft is clearly seen. Genital opening in the male is a small slit placed on the ninth segment in a slight depression with two elevations on either side. In the female the opening is found on the eighth segment with two raised elevations on either side. Anal opening is in the form of an elongated slit on the ventromeson of the tenth segment. Abdominal segments four, five and six have slight freedom of movement.

Length o female pupa 19-23 mm., greatest width 3-4 mm.

Length of male pupa 14-18 mm., greatest width 2·5-3 mm.

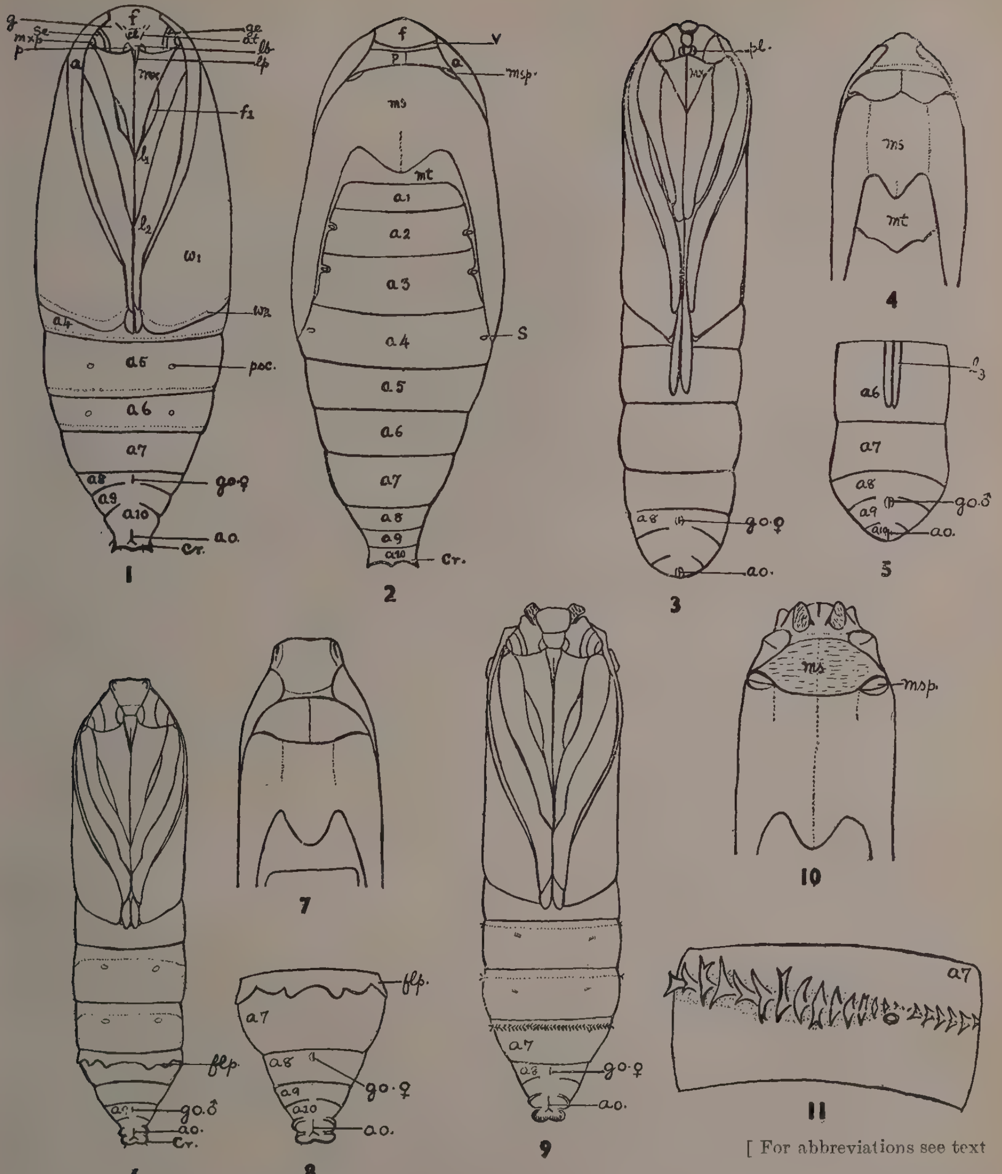
2. *Argyria sticticraspis* Hmpsn.

(Plate XLVI, fig. 2; Plate XLVII, figs. 6-8)

Colour usually yellowish H brown; abdomen lighter in colour. Vertex is indicated as a narrow piece in front of prothorax. Epicranial suture is indicated. Front is concave from above with two horn-like projections on either side above the eyepieces. Fronto-cylpeal suture is indistinct. Clypeus is separated from labrum by a deep furrow. Labial palpi is indicated as a narrow piece between the maxillae. Eyepieces are dark and prominent. Glazed and sculptured eyepieces are almost of equal width. Genae are well developed. Pilifers are small. Maxillae are half the length of the wings. Maxillary palpi present as a small triangulr piece between the eye and the antenna. Antennae are three-fourths the length of the wings. Prothorax is darker, shining and with a median ridge and raised lines on it. Prothoracic legs are about five-eighths the length of the wings. Prothoracic legs do not extend beyond the sculptured eyepiece and antenna. A portion of femur of the prothoracic leg is exposed. Mesothoracic spiracles appear as small, elongated slits with indistinct ridges. Mesothoracic legs less than the wings. Metathoracic legs are as long as the wings. Abdominal spiracles with dark brown rim and clear elliptical openings. Abdominal segments five, six and seven are provided with prominent ridges or flanged plates. These flanged plates are continuous and make a complete circle on segment seven. On segments five and six the flanged plates stop short near the spiracles and are continued ventrally as faint wavy lines. Abdominal segments are covered with numerous minute conical spines. These spines come closer and fuse together to form the flanged plates. These are supposed to prevent the telescoping of the free segments. In addition to these, the caudal margins of segments four, five and six are provided with a network of lightly chitinized ridges. Genital opening in the female is a small slit on the ventral side of the eighth segment. In the male the genital opening is found on the ninth segment with two small raised papillae on either side. Tenth segment is produced into a very short, blunt cremaster with fairly deep lateral grooves. Cremaster consists of dorsal and ventral halves, each carrying two lobes with chitinized edges. Anal opening in the form of a slit terminating in two lines (in the form of an inverted λ). There is freedom of movement between the abodminal segments four and five, five and six, and six and seven.

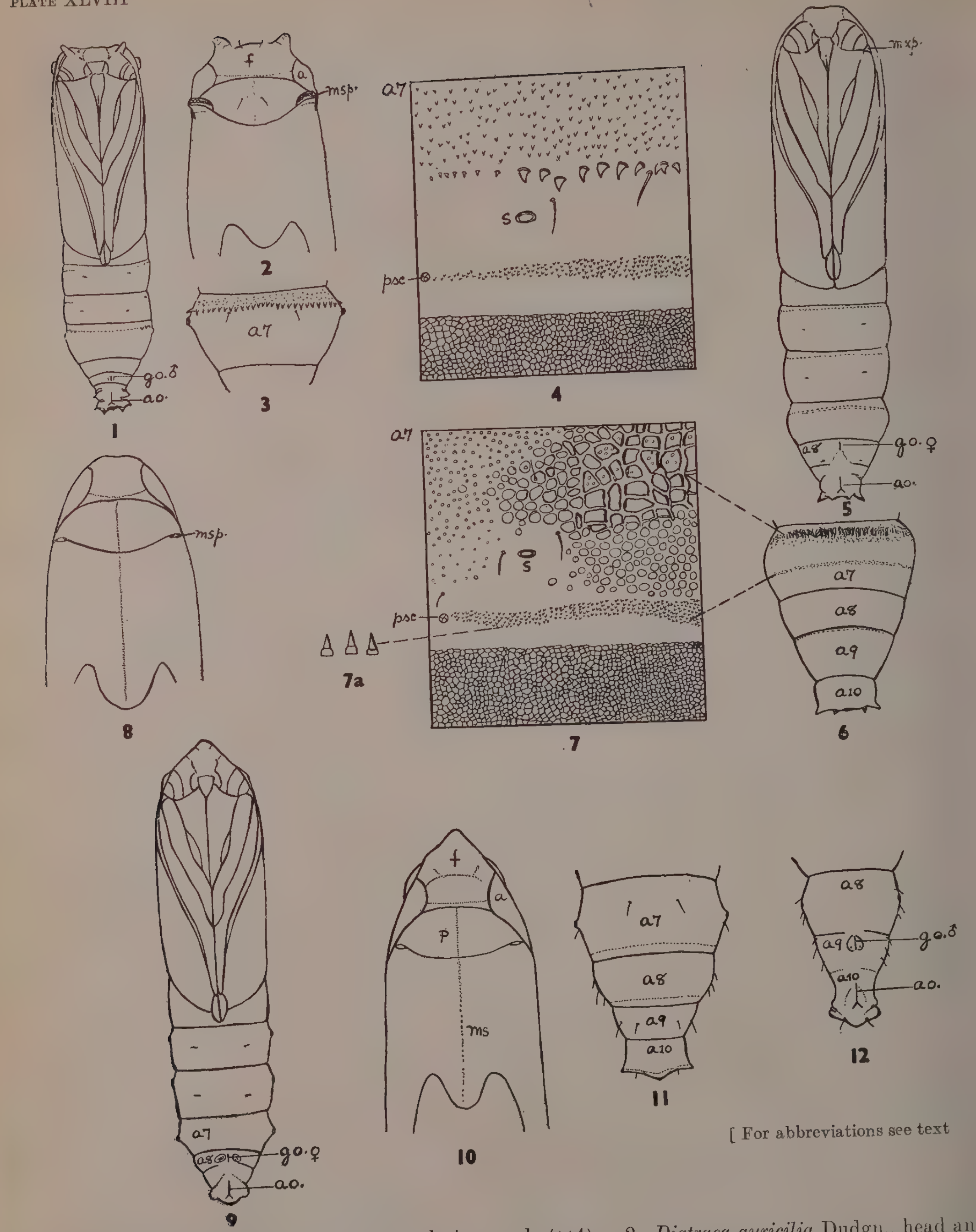
Length of female pupa 14-16 mm., greatest width 3·5-4 mm.

Length of male pupa 12-14 mm., greatest width 2·5-3 mm.



[For abbreviations see text

1. Hypothetical pupa, ventral view; 2. Hypothetical pupa, dorsal view; 3. *Scirpophaga nivella* F., ventral view, female (×4); 4. *Scirpophaga nivella* F., head and thorax, dorsal view, female, (×4); 5. *Scirpophaga nivella* F., anal segment, ventral view, male (×6); 6. *Argyria sticticraspis* H., ventral view, male (×4); 7. *Argyria sticticraspis* H., head and thorax, dorsal view, female (×4); 8. *Argyria sticticraspis* H., anal segment, ventral view, female, (×4); 9. *Argyria tumidicostalis* H., ventral view, female, (×4); 10. *Argyria tumidicostalis* H., head and thorax, female (×4); 11. *Argyria tumidicostalis* H., fifth abdominal segment, side view, enlarged



[For abbreviations see text

1. *Diatraea auricilia* Dudgn., ventral view, male (×4); 2. *Diatraea auricilia* Dudgn., head and thorax, dorsal view, male (×6); 3. *Diatraea auricilia* Dudgn., seventh abdominal segment, dorsal view, male (×6); 4. *Diatraea auricilia* Dudgn., fifth abdominal segment, diagrammatic; 5. *Diatraea venosata* Wlk., ventral view, female (×4); 6. *Diatraea venosata* Wlk., anal end, dorsal view, female (×6); 7. *Diatraea venosata* Wlk., fifth abdominal segment diagrammatic; 7a. *Diatraea venosata* Wlk., spines from fifth abdominal segment, highly enlarged; 8. *Diatraea venosata* Wlk., head and thorax, dorsal view, female (×6); 9. *Chilo trypetes* Bisset, ventral view, female (×4); 10. *Chilo trypetes* Bisset, head and thorax, dorsal view, female (×6); 11. *Chilo trypetes* Bisset, anal end, dorsal

3. Argyria tumidicostalis Hmpsn.

(Plate XLVI, fig. 3 ; Plate XLVII, figs. 9-11)

Colour yellowish-brown ; face parts and prothorax dark reddish-brown ; abdominal segments shining. Caudal margins of the abdominal segments five to nine are darker in colour. Vertex indicated as a narrow strip bounded cephalad by the epicranial suture. Front well developed and extends upward into two chitinized ridge-like projections. Clypeus distinct and fronto-clypeal suture not indicated. Labrum separated from the clypeus by a faint depression. The invaginations for the anterior arms of the tentorium are indicated. Glazed and sculptured eyepieces are almost of equal width. Pilifers are well developed. Genae are provided with horn-like projections anteriorly, above the eyes. Labial palpi present as a triangular piece in-between the maxillae. Maxillae prominent and half the length of the wings. Maxillary palpi are indicated laterad of the eyes. Antennae three-fourths the length of the mesothorax ; meson with the median ridge and impressed lines over it. Prothoracic legs do not extend cephalad between the sculptured eyepiece and the antennae. A portion of femur of the prothoracic leg is exposed. Mesothorax $1\frac{1}{2}$ times as long as the longest abdominal segment. Mesothoracic spiracles are provided with semi-lunar chitinized ridges caudally. Mesothoracic legs slightly less than the wings. Metathoracic legs as long as the wings. Wings reach the midventer of the fourth abdominal segment. Abdominal spiracles are provided with elliptical openings and dark rim all round. Spiracles on eighth abdominal segment indistinct. Abdominal segments four, five and six are movable in both sexes. Abdominal segments five, six and seven are provided with a more or less complete circle of prominent and distinct double spines. These spines are slightly bent, pointed and highly chitinized. On segments five and six these spines stop short near the spiracle and are continued ventrally as a row of fine tubercles. The spines on segment seven are continuous. All the abdominal segments are beset with numerous transverse rows of minute conical spines. The large double spines are formed as a result of the fusion of these microscopic conical spines. Caudal margins of segments four, five, and six are provided with a network of more or less regular polygonal areas and a band of minute conical spines above them. These together with the large double spines prevent the telescoping of the free segments. Genital opening in the male is a small slit on the ninth segment with two small raised elevations on either side. In the female it is placed on the eighth segment. Anal opening is placed on the tenth segment and is in the form of a slit ending in two lines (λ). Tenth segment carries a very short cremaster with lateral grooves. The dorsal half of the cremaster consists of two short chitinized lobes.

Length of female pupa 16-18 mm., greatest width 4-5 mm.

Length of male pupa 13-15 mm., greatest width 3·5-4 mm.

4. Diatraea auricilia Dudgn.

(Plate XLVI, fig. 4 ; Plate XLVIII, figs. 1-4)

Head and thorax reddish-brown and abdominal segments of a dirty brown colour. Front is slightly concave from above. Vertex is reduced to

two triangular pieces above the prothorax. Epicranial suture is distinct Pilifers are present. Eyes are dark in colour and the eyepieces are of equal width. Genae are produced into two chitinized horn-like projections on either side above the eyes. Clypeo-labral suture is indicated. Labrum is provided with a notch caudally. Labial palpi is present. Antennae four-fifths the length of the wings. Maxillary palpi present as a small triangular piece laterad of the eyes. Prothoracic legs three-fifths the length of the wings. Prothoracic legs do not extend beyond the eyepieces and antennae. A small portion of the femur of prothoracic leg is seen. Mesothoracic spiracles are provided with very prominent arching tubercles below, which appear like rosettes. These tubercles are covered with very fine microscopic spines. Mesothoracic legs almost as long as the wings. Metathoracic legs slightly longer than the wings. Abdominal spiracles are slit-like, surrounded by reddish brown edges and placed on raised papillae. Caudal margins of the abdominal segments four to six are provided with a network of microscopic chitinized ridges, followed by several rows of minute conical spines. Cephalic margins of segments five to seven are provided with a few microscopic spines. In addition to these, on segments five, six and seven there are incomplete circles of prominent, straight spines, placed apart, mostly on the dorsal and lateral regions nearer the cephalic margins. There is one row of such spines on segments five and six ; sometimes two to three rows on segment seven. Spines on segment seven extend beyond the spiracles to some distance. The slit-like genital opening in the female is placed on the eighth segment. Genital opening in the male is a long slit on the ninth segment. Tenth segment is produced into a short cremaster with lateral grooves ; the dorsal half consists of four spines in two groups of two each and the ventral one carries two spines. Anal opening in the form of a slit ending in two lines (λ) situated on the ventromeson of the tenth segment. Abdominal segments four, five and six exhibit freedom of movement.

Length of female pupa 14-16 mm., greatest width 3-4 mm.

Length of male pupa 10-11 mm., greatest width 2·5-2·75 mm.

5. *Diatraea venosata* Walk.

(Plate XLVI, fig. 5 ; Plate XLVIII, figs. 5-8)

Colour usually dark chestnut-brown. Dorsal side is darker in colour and has a roughened appearance. Head appears more or less flat from above. Vertex is reduced to two small triangular pieces just above the prothorax. Epicranial suture is visible as a faint line. Front is well developed. Fronto-clypeal suture is indistinct. Pilifers and labial palpi are present. Labrum is present as a triangular piece caudad of the clypeus. The invaginations for the anterior arms of the tentorium are indicated. Glazed and sculptured eyepieces are almost of equal width. Face parts and the limbs have a finely pitted appearance. Maxillae half the length of the wings. Maxillary palpi are present. Antennae four-fifths the length of the wings. Mesothoracic legs less than the wings. Mesothoracic spiracles provided with slit-like opening and reddish brown edge. Abdominal segments one to seven are provided with a network of irregular chitinized ridges towards the margins which present a roughened appearance. On segments four to seven the

irregular chitinized ridges towards the dorso-cephalic margins are highly chitinized and very prominent. The ridges on the caudal margins of segments four to six are very regular and consist of rows of polygonal areas. In addition, on segments one to seven, just above the chitinized ridges, there are several rows of minute conical spines. These spines on segments four to six appear as glistening white streaks, in fresh specimens. Segments eight and nine are provided with numerous minute spines. Proleg scars are indicated on abdominal segments five and six. Genital opening in the female is a small slit near the cephalic margin of the eighth segment. In the male it is found on the ninth segment. Anal segment is produced into a very short, blunt cremaster with lateral grooves. The dorsal half of the cremaster carries four spines, two large and two small, in two groups of two each on either side. The ventral half is fairly smooth and rounded. Anal opening is in the form of a slit ending in two lines (λ) on the tenth segment. Abdominal segments four, five and six are free.

Length of female pupa 17·5-19 mm., greatest width 3·5-4 mm.

Length of male pupa 12·5-13·5 mm., greatest width 2·5-3 mm.

6. *Chilo trypetes* Bisset

(Plate XLVI, fig. 6; Plate XLVIII, figs. 9-12)

Pupa appears elongated and slender. Head, thorax and appendages yellowish=brown. Abdomen lighter in colour, with broad reddish-brown stripes along the spiracular region on either side. Face parts, appendages and thoracic segments appear shining and the rest of the body rather dull in appearance. Vertex is present as a narrow strip. Epicranial suture is visible. Front is produced anteriorly and appears as a conical horn-like projection from above. The fronto-clypeal suture is indistinct. Labrum is represented by a narrow strip between the eyes. Labial palpi not indicated. Glazed and sculptured eyepieces are almost of equal width. Pilifers are present. Maxillae half the length of the wings. Gena indicated as a smooth area above the eyes. Maxillary palpi present as small areas laterad of the eyes. Median ridge on the thorax is very prominent. Prothoracic legs five-eighths the length of the wings. Mesothoracic legs slightly shorter than the wings. Mesothoracic spiracles slit-like. Metathoracic legs slightly longer than the wings and reach the middle of the fourth abdominal segment. Abdominal segments are provided with numerous microscopic conical spines. These spines are more numerous towards the caudal margins of segments four to six. The body setae are very prominent on the abdominal segments. Genital opening in the female is a small slit extending from about the middle of the eighth abdominal segment to the cephalic margin of the ninth abdominal segment. The opening is placed in a slight depression with two brownish, prominent tubercles on either side. In the female it is placed on the caudal margin of the ninth segment with two brownish tubercles on either side. Anal segment is produced into a very short, blunt cremaster with lateral grooves. The dorsal half of the cremaster consists of a broad ridge with three indistinct spine-like lobes. The ventral half is fairly smooth and without any spines. Anal opening is

in the form of a slit ending in two lines (λ) on the ventromeson of the tenth segment. Proleg scars are indicated on segments five and six. There is freedom of movement between segments four and five, five and six, and six and seven.

Length of female pupa 15-18 mm., greatest width 3·5-4 mm.

Length of male pupa 13-13·5 mm., greatest width 2·5-3 mm.

7. *Chilo zonellus* Swinh.

(Plate XLVI, fig. 7 ; Plate XLIX, figs. 1-3)

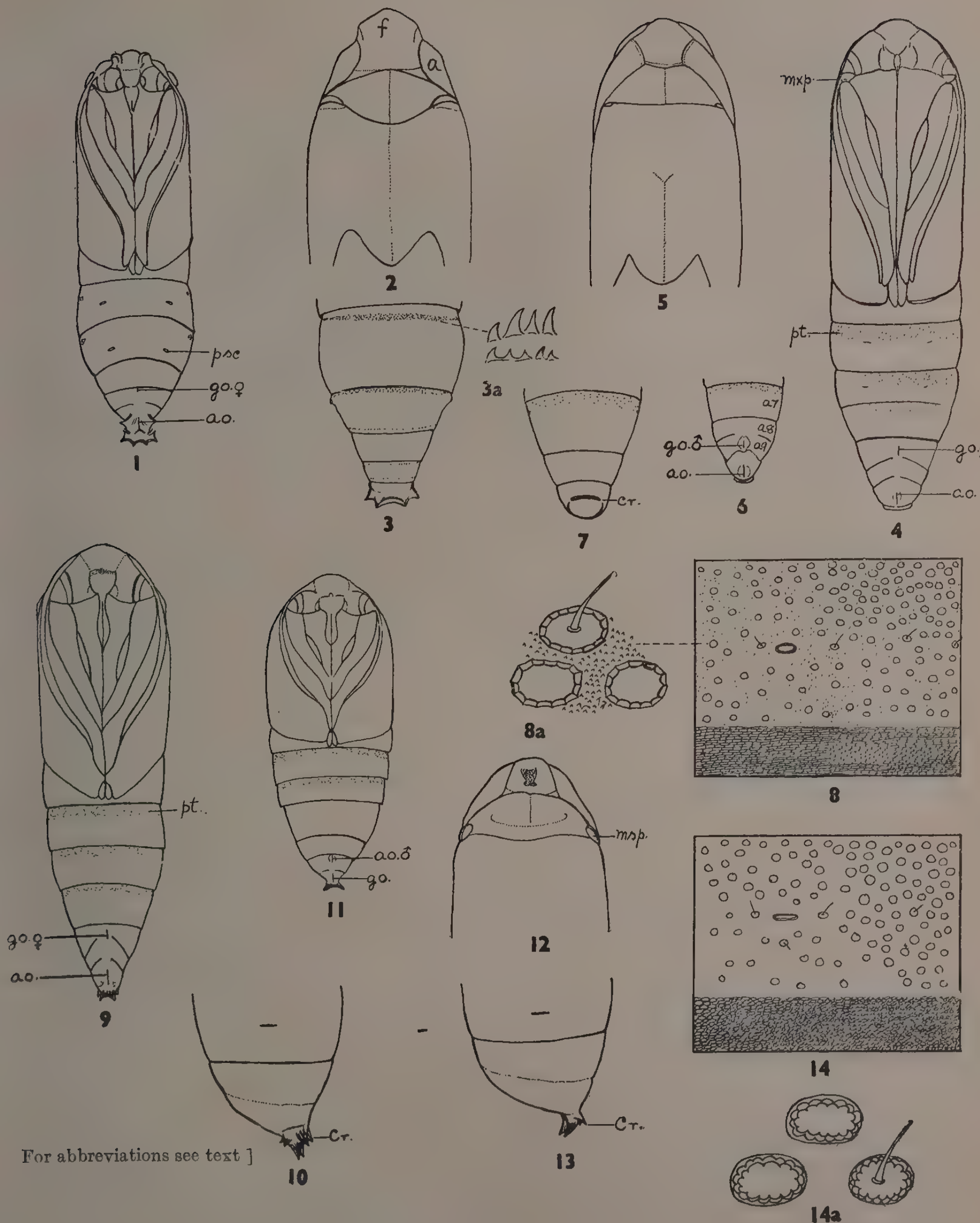
Pupa appears bent. Colour usually reddish-yellow. Eyes darker in colour. Vertex shining and indicated as a narrow strip. Epicranial suture is distinct. Front is flat from above and slightly produced anteriorly. Clypeus is prominent and slightly bulged out. Fronto-clypeal suture is indistinct. The invaginations for the anterior arms of the tentorium indicated. Labrum is separated from the clypeus by a deep furrow. Eye-pieces are of almost equal width. Pilifers and maxillary palpi are indicated. Genae are produced above into two horn-like ridges with shallow depressions in the centre. Labial palpi are present. Maxillae half the length of the wings. Prothorax about one-third the length of the mesothorax ; reddish in colour and with a median ridge and indefinite elevated lines on it. Prothoracic legs five-eighths the lenghth of the wings. A portion of the prothoracic femur is exposed. Mesothorax shining, and with impressed lines on it. Mesothoracic legs almost as long as the wings. Mesothoracic spiracles with reddish elevated ridges, caudally. Metathoracic legs slightly longer than the wings. Wings reach almost the caudal margin of the fourth abdominal segment. Abdominal segments smooth, shining. Abdominal spiracles with slit-like opening and slightly raised reddish rim. Abdominal segments are provided with numerous rows of microscopic conical spines. Caudal margins of segments four to six are provided with a network of more or less regular polygonal areas. In addition, the cephalic margins of segments five to seven are provided with six to nine rows of prominent, short, conical spines, which stop short near the spiracle. These spines are quite different from those of *Diatraea auricilia* Dudgn. in structure and arrangement. The spines here are not distinct and separate as in *D. auricilia* and moreover are arranged in more than one row. The margins of these segments present a rough appearance due to the presence of these spines. Proleg scars are seen on segments five and six. Anal segment is provided with a short, blunt, cremaster with deep lateral grooves. Cremaster consists of a dorsal half with six short spines, in two groups of three each, arranged in a triangle on either side. Genital opening in the female is a small slit near the cephalic margin of the eighth segment. In the male the genital opening is placed on the ninth segment with raised papillae on either side. Anal opening is in the form of a slit terminating in two lines (λ) on the tenth segment. Abdominal segments four to six are free in both sexes.

Length of female pupa 12·5-17 mm., greatest width 3-4 mm.

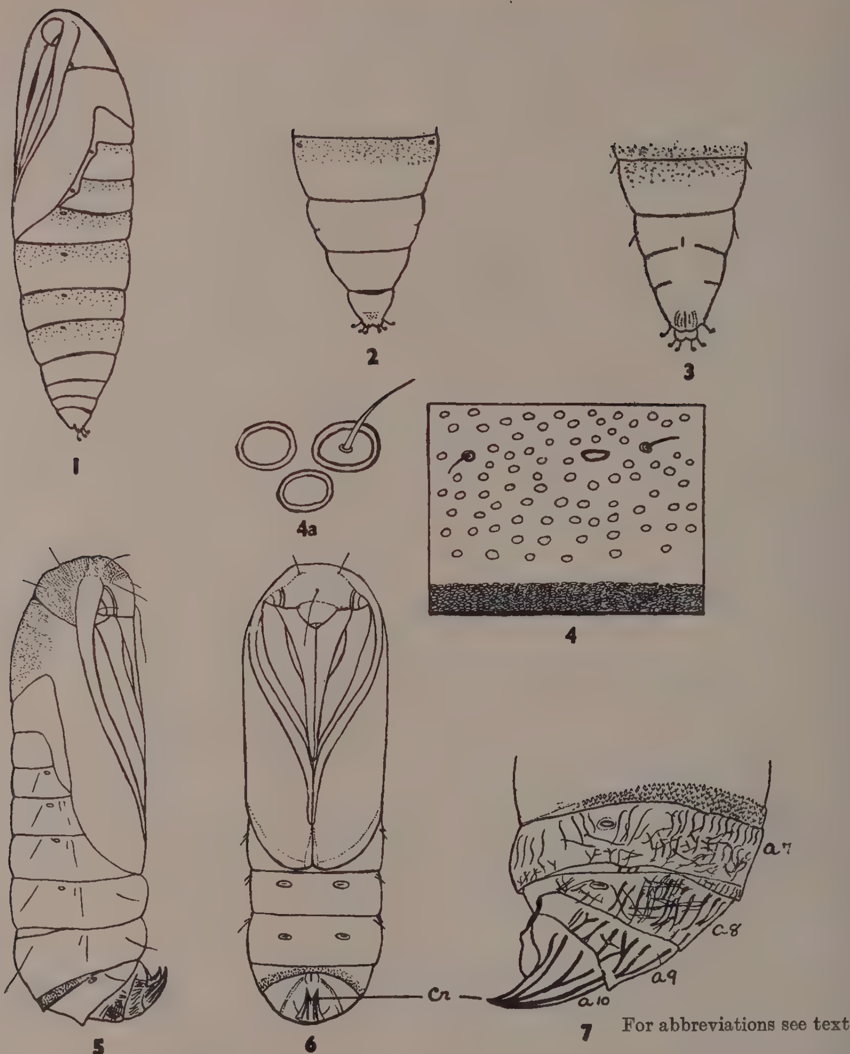
Length of male pupa 10·5-13 mm., greatest width 2·5-3 mm.

PLATE XLIX

1. *Chilo zonellus* Swinh., ventral view, female (×4); 2. *Chilo zonellus* Swinh., head and thorax, dorsal view, female (×6); 3. *Chilo zonellus* Swinh., anal segment, dorsal view, female (×6); 3a. *Chilo zonellus* Swinh., spines from fifth abdominal segment, highly magnified; 4. *Emmalocera depressella* Swinh., ventral view, female (×4); 5. *Emmalocera depressella* Swinh., head and thorax, dorsal view, female (×4); 6. *Emmalocera depressella* Swinh., anal end, ventral view, male (×4); 7. *Emmalocera depressella* Swinh., anal end, dorsal view, femaie (×4); 8. *Emmalocera depressella* Swinh., fifth abdominal segment, diagrammatic; 8a. *Emmalocera depressella* Swinh., 'pits' from abdominal segment, highly enlarged; 9. *Sesamia uniformis* Dudgn., ventral view, female (×4); 10. *Sesamia uniformis* Dudgn., anal end, side view, female (×6); 11. *Sesamia inferens* Wlk., ventral view, male (×4); 12. *Sesamia inferens* Wlk., head and thorax, dorsal view, female (×6); 13. *Sesamia inferens* Wlk., anal end, side view, female (×6); 14. *Sesamia inferens* Wlk., fifth abdominal segment, diagrammatic; 14a. *Sesamia inferens* Wlk., 'pits' from abdominal segments, highly magnified



For abbreviations see text]



1. *Raphimetopus ablutella* Zell., side view., female (×4); 2. *Raphimetopus ablutella* Zell., anal end, dorsal view, female (×6); 3. *Raphimetopus ablutella* Zell., annal end, ventral view, female (×6); 4. *Raphimetopus ablutella* Zell., abdominal segment, diagrammatic; 4a. *Raphimetopus ablutella* Zell., 'pits' from abdominal segment, highly enlarged; 5. *Procometis trochala* Meyr., side view, female (×4); 6. *Procometis trochala* Meyr., ventral view, female (×4); 7. *Procometis trochala* Meyr., anal end, side view (×8)

8. Emmalocera depressella Swinh.

(Plate XLVI, fig. 8; Plate XLIX, figs. 4-8)

General colour is yellowish-brown. Cephalic margins of abdominal segments reddish-brown and pitted in appearance. Face parts and thorax shining and with impressed lines. Vertex is very much reduced and indicated as two triangular pieces on the inner side of the antennae. Epicranial suture is distinct. Front is smooth, rounded and slightly arched. Clypeus is well developed and the fronto-clypeal suture is indistinct. The fronto-clypeus is provided with a few transverse ridges. The clypeo-labral suture is also indicated. Pilifers are present. Glazed eyepiece is narrower than sculptured eyepiece. Genae are represented as smooth areas. Labial palpi are present. Maxillae are long, more than three-fourths the length of wings. Maxillary palpi are indicated as two large pieces latered of the eyes. Antennae shorter than maxillae. Prothoracic legs are half the length of the wings. Mesothoracic spiracles appear as small slits bounded caudally by small ridges. Mesothoracic legs shorter than wings. Metathoracic legs as long as the wings. Abdominal spiracles with elliptical opening and reddish rim. Abdominal segments one to nine are provided with numerous minute conical spines. In addition, the metathoracic segment and the first seven abdominal segments are provided with numerous oval 'pits', which are more numerous towards the cephalic margins of the free segments four, five and six. The body setae arise from the centre of these pits; each pit consists of a shallow depression in the middle and a chitinized rim all round. The rim appears to be made up of a number of flattened spines fused together. Besides these, the caudal margins of the abdominal segments four, five and six are provided with a network of ridges. Genital opening in the male is slit-like and placed in a shallow depression on the ninth segment with two small, raised elevations on either side. In the female the genital opening is found on the eighth segment. Anal opening is long and slit-like, and does not end in two lines as in the case of the striped borers. The dorsal part of the hind end of the pupa is rounded, smooth and with a transverse, chitinized ridge which represents the cremaster. There are no distinct spines or projections on the anal segment. Abdominal segments four, five and six are free.

Length of female pupa 15-17·5 mm., greatest width 3·5-5 mm.

Length of male pupa 10-13 mm., greatest width 2·5-3·5 mm.

9. Sesamia uniformis Dudgn.

(Plate XLVI, fig. 9; Plate XLIX, figs. 9 and 10)

Head and thorax dark reddish-brown; abdomen yellowish-brown. Body much wider at the cephalic end and tapering gradually to the caudal end of the body. Vertex is very much reduced and indicated as two small triangular pieces. Fronto-clypeal region has a rough appearance. Front is provided with a chitinized oval tubercle in the middle. Fronto-clypeal suture is distinct. Clypeus is provided with a small globular tubercle on the caudal margin. Clypeo-labral suture is distinct. Pilifers and genae indicated. Sculptured eyepiece broader than glazed eyepiece. Labial palpi present as a long piece between the maxillae. Maxillae long and five-eighths

the length of the wings. Prothoracic legs extend a little beyond the sculptured eyepieces and antennae. Prothoracic legs are less than the maxillae. Mesothoracic legs seven-eighths the length of wings. Mesothoracic spiracles slit-like and with prominent oval, flattened tubercles, adjacent to their caudal margins. Metathoracic legs as long as the wings. A part of the prothoracic femur is exposed. Abdominal spiracles are elongated and slit-like. Abdominal segments one to eight, sometimes one to nine, with numerous oval 'pits', which are more numerous on the cephalic margins of the free abdominal segments four to six. Each pit consists of a shallow depression in the centre and a chitinized rim all round. The rim is made up of concentric rings of spine-like ridges. The body setae are always associated with the pits, as in *Emmalocera depressella*. Genital opening in both the sexes is found on the ninth abdominal segment in the form of an elongated slit. Anal opening is slit-like. Anal segment is produced into a distinct cremaster, which consists of a concave ventral portion carrying four spines at its tip and a straight dorsal portion with two spines at some distance apart. Abdominal segments four to six are free.

Length of female pupa 15-17·5 mm., greatest width 3·5-5 mm.

Length of male pupa 10-13 mm., greatest width 2·5-3·5 mm.

10. Sesamia inferens Walk.

(Plate XLVI, fig. 10; Plate XLIX, figs. 10-14)

Anal segment is produced into a distinct cremaster with a stalk, carrying four spines at its tip, two small and two big. Except for this distinct difference in the cremaster both the pupae of *Sesamia inferens* and *Sesamia uniformis* appear to be alike in the disposal of the different morphological structures.

Length of female pupa 15·5-17·5 mm., greatest width 3-4·5 mm.

Length of male pupa 10·5-12 mm., greatest width 2·5-3 mm.

11. Raphimetopus ablutella Zell.

(Plate XLVI, fig. 11; Plate L, figs. 1-4)

General colour is greenish brown. Abdominal segments are lighter in colour and have a pitted appearance due to the presence of numerous oval pits. The body is much wider at the cephalic end, gradually tapering towards the hind end. Mesothoracic spiracles are slit-like. Abdominal spiracles are provided with elliptical openings and slightly raised reddish rim. Abdominal segments one to seven are provided with numerous oval pits, which are more numerous towards the cephalic margins. These pits are quite different in structure from those of *Emmalocera depressella* Swinh. or *Sesamia* spp. The setae on the abdominal segments are always associated with these pits. Except for these pits, the abdominal segments are devoid of any prominent ridges or spines. Anal segment is made up of a lightly chitinized dorsal half, with two lobes pointing posteriorly and carrying six to ten long, brownish, circinate hairs. A transverse chitinized ridge is present on the cephalic margin of the dorsum of the anal segment. Anal opening is slit-like and situated on the ventromeson of the tenth segment. Genital

opening in the female is slit-like and placed on ventromeson of the ninth segment. Abdominal segments four, five and six are free in both sexes.

Length of female pupa 10-14 mm., greatest width 3·5-4 mm.

12. Procometis trochala Meyr.

(Plate XLVI, fig. 12; Plate L, figs. 5-7)

Pupa appears dark brown in colour and more or less cylindrical in shape. Head and thorax are rugose in appearance owing to the presence of fine ridges. Epicranial suture is distinct. Front is flat from above and carries two prominent setae on either side. Fronto-clypeal suture is indicated. Clypeus is well developed, with a long seta rising from the centre of it. A visible labial palpi is not indicated. Pilifers, genae and maxillary palpi are indicated. Prothoracic and mesothoracic legs do not extend between the eyes and antennae. Maxillae well developed and two-thirds the length of the wings. Prothoracic legs about half the length of the wings. Mesothoracic legs slightly less than the maxillae in length. Antennae seven-eighths the length of the wings. Metathoracic legs as long as the wings. Mesothoracic spiracles indistinct. Abdominal spiracles are provided with oval slits. Cephalic margins of abdominal segments are provided with an anastomosing network of chitinized ridges, which present a rough appearance. Caudal margins of segments three, four and five are provided with lightly chitinized, raised polygonal areas. In addition to these, the caudal margin of segment five has five to seven rows of pointed spines. Abdominal setae are very long and prominent. The last abdominal segments, seven to ten, are highly chitinized and with very prominent ridges. Anal segment is produced into a distinct cremaster, which consists of a pair of stout, prominent spines bent ventrally and joined at their bases. These spines are provided with prominent longitudinal ridges. Genital opening in both the sexes is in the form of an elongated slit on the ventromeson of the ninth abdominal segment. Anal opening is slit-like and placed on the ventral side of the anal segment. Abdominal segments four, five, and six are free.

Length of female pupa 11-14 mm., greatest width 3-4 mm.

Length of male pupa 10-11 mm., greatest width 2·5-3 mm.

Key to pupae of borers

1. Pupa with soft exterior; appendages partially soldered to the body; the tips of legs and wings free. Cremaster absent . . .	*Scirpophaga nivella* Fabr.
Pupa with hard exterior; appendages soldered down to the body to form a smooth exterior. Cremaster present	2
2. Pupa with short blunt cremaster and deep lateral grooves on the tenth abdominal segment. Anal opening in the form of slit ending in two lines (人)	3
Pupa with rounded and smooth anal end. Cremaster reduced and represented by a chitinized transverse ridge on the dorso-cephalic margin of the anal segment. Cephalic margins of abdominal segments with 'pits' and microscopic conical spines in between. Anal opening slit-like	7

Pupa with a distinct cremaster, with or without a distinct stalk. No lateral grooves on the tenth abdominal segment. Anal opening slit-like	8
3. Without ridges, distinct hooks or roughness on abdominal segments. Dorsal half of anal end with three indistinct spine-like projections posteriorly	*Chilo trypetes* Bisset.
With ridges, hooks or roughness on abdominal segments five, six and seven . . .	4
4. With incomplete circle of roughness on the cephalic margin of abdominal segments. Dorsal half of anal end with four spines, in two groups of two each, pointing posteriorly	*Diatraea venosata* Walk.
With complete circle of ridges or spines on the cephalic margin of abdominal segment seven	5
With incomplete circle of spines on the cephalic margin of abdominal segment seven .	6
5. Circle made up of flattened ridges (flanged plates) more or less joined together . .	*Argyria sticticraspis* Hmpsn.
Circle made up of distinct and separate double spines	*Argyria tumidicostalis* Hmpsn.
6. Spines on segment seven quite distinct and separate and extend beyond the spiracles. Dorsal half of anal end with four spines and the ventral with two spines . . .	*Diatraea auricilia* Dudgn.
Spines on segment seven not quite distinct and separate and do not extend beyond the spiracles. Dorsal half of anal end with six short spines in two groups of three each on either side	*Chilo zonellus* Swinh.
7. Anal end without any lobes or hairs . .	*Emmalocera depressella* Swinh.
Anal end with two lobes dorsally, which carry six to ten long, circinate hairs . . .	*Raphimetopus ablutella* Zell.
8. Cephalic margins of abdominal segments with 'pits'	9
Cephalic margins of abdominal segments with anastomosing chitinized ridges. Anal segment with a pair of stout, pointed spines, bent ventrally and joined at their bases .	*Procometis trochala* Meyr.
9. Anal segment with a stalk carrying four spines, two small and two large	*Sesamia inferens* Walk.
Anal segment with a ventral portion carrying four spines and a dorsal portion with two spines, six in all	*Sesamia uniformis* Dudgn.

Acknowledgements

This work was carried out under the Scheme for Research on Insect Pests of Sugarcane, financed by the Imperial Council of Agricultural Research.

REFERENCES

Chapman, T. A. (1893). *Trans. ent. Soc. London*, pp. 97-119; 255-65

————(1894). *Trans. ent. Soc. London*, pp. 335-50

————(1896). *Trans. ent. Soc. London*, pp. 129-47

Fletcher, T. B. (1928). *Report of the Imperial Entomologist, Sci. Rept. Agric. Res. Inst. Pusa, 1926-27*, pp. 56-67

Fletcher, T. B. and Ghosh, C. C. (1919). *Rept. Proc. Third ent. Meeting, Pusa,* pp. 368-9 (Also published as *Bull. No.* **102**, *Agric. Res. Inst., Pusa*)
Ghosh, C. C. (1921). *Rept. Proc. Fourth ent. Meeting Pusa,* p. 114 (Also published as *Bull. No.* **134**, *Agric. Res. Inst., Pusa*)
Gupta, B. D. (1940). *Indian J. agric. Sci.* **10,** 787-817
Mosher, E. (1916). *Bull. Illinois State Lab. Nat. Hist.* **12,** 1-159
———— (1917). *Maine Agric. Expt. Stn. Bull. No.* **259**
Packard, A. S. (1895). *Mem. Nat. Acad. Sci.* **7,** 56-83
Scudder, S. H. (1889). *The Butterflies of the Eastern United States and Canada* (3 Vols.)

LIST OF ABBREVIATIONS USED IN PLATES XLVII-L

a	= antenna
al — a 10	= abdominal segments 1-10
ao.	= anal opening
at.	= invaginations for the anterior arms of the tentorium
ct.	= clypeus
cm.	= cephalic margin of abdominal segments
cr.	= cremaster
es.	= epicranial suture
f.	= front
fl.	= femur of prothoracic leg
fcs.	= fronto-clypeal suture
fp.	= flanged plate
g.	= gena
ge.	= glazed eyepiece
go.	= genital opening
lb.	= labrum
l_1	= prothoracic leg
l_2	= mesothoracic leg
l_3	= metathoracic leg
lp.	= labial palpi
ms.	= mesothorax
msp.	= mesothoracic spiracle
mt.	= metathorax
mp.	= maxillary palpi
mx.	= maxilla
p.	= prothorax
pl.	= pilifers
psc.	= proleg scar
pt.	= 'pits'
s.	= spiracle
se.	= sculptured eyepiece
v.	= vertex
w_1	= mesothoracic wing
w_2	= metathoracic wing

SCALE INSECTS OF THE PUNJAB AND NORTH-WEST FRONTIER PROVINCE USUALLY MISTAKEN FOR SAN JOSÉ SCALE (WITH DESCRIPTIONS OF TWO NEW SPECIES)

BY

KHAN A. RAHMAN, B.Sc. Ag. (Edin.), Ph.D. (Cantab.)

AND

ATIQUR RAHMAN ANSARI, M.Sc. Ag.

Punjab Agricultural College, Lyallpur

abstr. by
C. D. F.

(Received for publication on 11 July 1940)

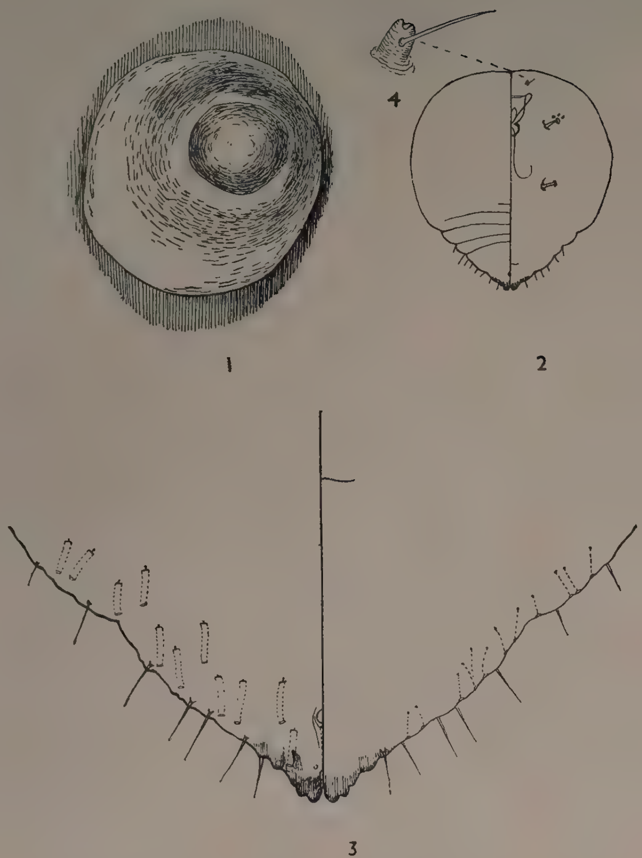
(With Plates LI—LIII)

THE Imperial Council of Agricultural Research, India, sanctioned a scheme, in April 1937, for three years to carry out a survey of the Punjab and the N.-W. F. Province in order to find out the distribution and food-plants of San José scale, a well-known pest of deciduous fruit trees in many parts of the world [Rahman, 1940]. This survey has brought to light the existence of a number of economic Coccidae—including two new species—which closely resemble San José scale either in their morphology or symptoms of their attack, and as such are usually mistaken for it. This paper is an attempt to bring together briefly the differentiating structural and other peculiarities of these forms with a view to ensuring their correct identification.

Tentative key to differentiate the species recorded in this paper

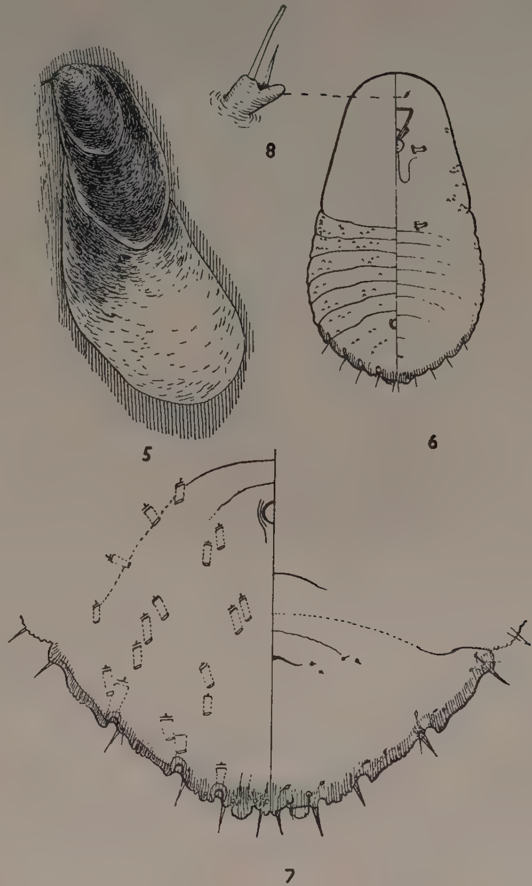
1 (14) One-barred dorsal ducts present
2 (13) Never enclosed in puparium
3 (12) Pygidium with paraphyses or densariae
4 (11) Pygidium with three well-developed lobes
5 (10) Thoracic tubercles absent
6 (9) Ventrum without perivulvar pores
7 (8) Ventrum with three scleroses....*Aonidiella aurantii* (Mask.)
8 (7) Ventrum with one sclerosis......*Aonidiella citrina* (Coq.)
9 (6) Ventrum with five groups of perivulvar pores......*Aonidiella orientalis* (Newst.)
10 (5) Thoracic tubercles present.... .....*Chrysomphalus ficus* Ashm.
11 (4) Pygidium with two well-developed and one poorly developed lobes.......*Quadraspidiotus* (*Aspidiotus*) *perniciosus* (Comst.)
12 (3) Pygidium without paraphyses or densariae......*Aspidiotus destructor* Sign.
13 (2) Always enclosed in II stage nymphal skin......*Aonidia zizyphi* sp. n. (Plate LI, figs. 1-4)
14 (1) Two-barred dorsal ducts present
15 (18) Ventrum with perivulvar pores

Aonidia zizyphi



1. Female scale ; 2. Female ; 3. Pygidium ; 4. Antenna of adult female

Lapazia peshawarensis



5. Female scale ; 6. Female ; 7. Pygidium ; 8. Antenna of adult female

16 (17) Ventrum with five groups of perivulvar pores......*Parlatoria oleae* (Colv.)
17 (16) Ventrum with four groups of perivulvar pores......*Parlatoria pseudopyri* Kuw.
18 (15) Ventrum without perivulvar pores ...*Lapazia peshawarensis* sp. n. (Plate LI, figs. 5-8)

Identifications were confirmed by Dr R. Takahashi of Agricultural Research Institute, Taihoku, Formosa, through the British Museum, London.

1. *Aonidiella aurantii* (Mask.) ; California red scale
Newstead, R. 1901 Mon. Brit. Cocc. *London*, I : 88

Distribution

Punjab.—Ahmadgarh (Malerkotla State), Ambala, Alipur, Cambellpur, Changamanga, Dasua, Gangapur, Gobindgarh (Nabha State), Gujranwala, Gujrat, Gutkar (Mandi State), Jhelum, Jind, Kahuta, Kalka, Kotgarh, Lahore, Lyallpur, Malerkotla, Montgomery, Multan, Muzaffargarh, Nabha, Phagwara, Sangrur (Jind), Sargodha, Sialkot, Taxila, Una.

N.-W. F. Province.—Bannu, Charsadda, Darband, Darsamand, D. I. Khan, Gardi, Ghoriwala, Jamal-garhi, Kohat, Mardan, Peshawar, Phulera State, Tarujabba, Thall, Thana and Totkan (Malakand Agency) and Totkas.

It has also been recorded from Ceylon, Coimbatore, Dhamdha, Godavari-Palghat, Pusa, and Someshwaram in South Kanara [Ramachandran and Ayyar, 1934].

Food plants

It is abundant on leaves, bark and fruit of *Citrus* spp. (*chakotra*, *galgal*, grape-fruit, *kimb*, lemon, Malta, oranges, etc.) (Plate LII, fig. 1). It has also been found fairly abundant on *Aegle marmelos*, *Agave* sp., *A. variegata*, *Aloe vera*, *Alstonia scholaris*, *Bauhinia alba*, *B. racemosa*, *Bombax malabaricum*, *Broussonetia papyrifera*, *Canna indica*, *Cassia fistula*, *Cassia* sp., *Cordia myxa*, *Diospyros montana*, *Dombeya acutangula*, *Eucalyptus* sp., *Euonymus juponicus*, *Ficus* sp., *F. bengalensis*, *F. elastica*, *F. religiosa*, *F. roxburghii*, *Grevillea robusta*, *gul-i-fanus* (*Lagerstroemia indica*), *Hibiscus* sp., jasmine (*Jasminum pubescens* and *J. sambac*), *jaman* (*Euginia jambolana*), *Mangifera indica*, *Morus alba*, *Murraya exotica*, *Musa sapeientum*, *Nerium odorum*, *N. oleander*, *Poinsettia* sp., *Pongamia glabra*, *Psidium guyava*, *Rosa* spp., *Tecoma* spp., *Vitis vinifera*, *Vitis* sp. and *Zizyphus* spp.

Other workers have found it on the following food-plants also. *Agave americana*, *Aloes* sp., *Camellia thea*, *Coffea arabica*, *Cycas circinalis*, *C. recurvata* and *Morinda tinctoria* [Ramachandran and Ayyar, 1934].

Chief characters

Female scale.—Length 1·72 mm., breadth 1·65 mm., thin, almost circular, slightly convex, yellowish gray, reddish because of the red female which shows through. Exuviae brilliant orange, central.

Female.—Length 0·88-1·20 mm., breadth 0·98-1·36 mm., pyriform and yellow in early adult life, becoming strongly reniform and reddish brown at maturity. Cephalo-thoracic region produced posteriorly forming two convergent lobes which enclose the pygidium.

Pygidium with four pairs of lobes : I pair of lobes largest distinctly separated, disto lateral margins emarginate, distal margin rounded. II pair smaller, otherwise similar to the I pair; some specimens, however, may have the inner margins entire. III pair smaller than II, their inner margins entire, but outer margins distinctly wavy medially. IV pair very poorly developed, triangular.

Incisurae present, filled with serrated plates : I incisura with two slender plates, which are serrated distally. II incisura with two plates, inner plate with its apex serrated and with a median serration laterally and the outer plate bifurcated apically, furcae seratted. III incisura with two stout plates, the inner one deeply bifurcated distally, each branch being serrated along the outer margin and pointed distally, the outer plate deeply serrated on the apex and along its outer margins. IV incisura with three stout plates deeply bifurcated apically, inner branch being slightly, and the outer branch deeply, serrated.

About 12 long, filiform, one-barred, sub-dorsal ducts connected with rows of dorsal pores, disposed of in definite groups ; six pairs of paraphyses or the dorsal club-shaped thickenings are also present.

Ventrum furnished with three heavily sclerotized bodies, one of which has usually a globular inverted V- or U-shaped apophyses. Perivulvar pores absent.

This species resembles San José scale in the general appearance of the scale and in the general shape and colour of the body of the female. It differs from San José scale in : (1) the female becoming red and strongly reniform in shape at period of gestation, (2) the female pygidium having three well-developed and one very poorly developed pair of lobes, (3) the presence of a group of small scleroses on ventrum, and (4) having six pairs of club-shaped paraphyses.

2. *Aonidiella citrina* (Coq.) : Yellow scale

Ferris, G. F. 1938 : Atlas of the scale insects of North America, *S. 11 : 119*

Distribution

Bannu and D. I. Khan in the N.-W.F. Province and Lyallpur and Nabha in the Punjab.

Food plants

Citrus spp. and *jaman* (*Eugenia jambolana* ; Plate LII, fig. 2). The leaves infested with this scale show many yellow spots or streaks where the chlorphyll has been destroyed ; green fruit too may show such spots. *Jaman* leaves develop red spots.

Chief characters

Female scale.—Length 1·64-1·7 mm., breadth 1·51-1·6 mm., thin, more or less circular ; slightly convex, yellow because of the yellow female which shows through. Exuviae yellow, central or shifted very slightly to one side.

FIG. 1. Citrus leaf infested with *Aonidiella aurantii* (Mask.)

FIG. 2. *Jaman* leaf infested with *Aonidiella citrina* (Coq.)

FIG. 3. *Shisham* leaf infested with *Aonidiella orientalis* (Newst.)

Fig. 1. *Ber* twig infested with *Aonidia zizyphi* sp. n.

Fig. 2. Peach leaf infested with *Parlatoria oleae* (Colv.)

Fig. 3. Rose twig infested with *Parlatoria pseudopyri* Kuw.

Female.—Length 0·97-1·19 mm., breadth 1·00-1·06 mm., pyriform and whitish yellow in early adult life, becoming strongly reniform and yellow at maturity.

Pygidium with four pairs of lobes : I pair of lobes largest, distinctly separated, disto-lateral margins emarginate, distal margins rounded. II pair of lobes smaller, otherwise similar to the I pair. III pair of lobes smaller than II, with lateral margins irregular medially. IV pair of lobes poorly developed, triangular.

Incisurae present, filled with serrated plates : I incisura with two slender plates, which branch profusely distally. II incisura with two plates, outer margins of which are serrated along their distal halves. III incisura with one stout plate, which is deeply bifurcated, each bifurcation being serrated along the distal and lateral margins. IV incisura with three stout plates, each of which is bifurcated apically, each one of the inner bifurcation being slightly serrated and each one of the outer bifurcation being with deeper serrations.

Twelve long, filiform, one-barred, sub-dorsal ducts connected with rows of dorsal pores, disposed of in definite groups ; four pairs of paraphyses also present.

Ventrum furnished with one slender, acute inverted V-shaped sclerotized apophyses [Ferris, 1938]. Perivulvar pores absent.

This insect resembles *A. aurantii* and can be differentiated from San José scale by the characters mentioned under it. It can be differentiated from *A. aurantii* by the presence of only one narrow inverted V-shaped apophysis.

3. *Aonidiella orientalis* (Newst.) : Oriental yellow scale

Ferris, G. F. 1938 : Atlas of the scale insects of North America, *S. II* : *120*

Distribution

Punjab.—Ahmadgarh (Bahawalpur State), Bahawalpur, Bilaspur, Darbhanga, Dera Nawab (Bahawalpur State), Dujana, Hoshiarpur, Jind, Jullundur, Lahore, Lyallpur, Montgomery, Muzafargarh, Nahar (Dujana State), Nabha, Pataudi, Sangrur, Sufidan (Jind State), and Texila.

N.-W. F. Province.—Bannu, Nowshera and Thall.

It has also been recorded from Aleppey, Calcutta, Ceylon, Coimbatore, Dhamdha, Guntur, Kistna, Muzaffarpur, Pusa, Rajnagar, and Tinnevelly [Ramachandran and Ayyar, 1934].

Food plants

Acer oblongum, *A. pictum*, *Adhatoda vasica*, *Aegle marmelos*, *Agave* sp., *A. americana*, *A. variegata*, *Ailantus aladulosa*, *Albizzia* sp., *A. lebbek*, *Aloe vera*, *Alpinia nutans*, *Alstonia* sp., *A. scholaris*, *Antigonon leptopus*, *Aristolochia* sp., *Asparagus* sp., *Averrhoa carambola*, *Barleria cristata*, *Bassia latifolia*, *Bauhinia alba*, *B. purpurea*, *B. racemosa*, *B. vahlii*, *B. variegata*,

ber (*Zizyphus* sp., *Z. jujuba*, *Z. oenoplia*), *Bignonia radicans*, *B. vinusta*, *Bischofia javanica*, *Bixineae* sp., *Bombax malabaricum*, *borh* (*Ficus bengalensis*) *Boswellia serrata*, *Bougain vielae mrs butt*, *Buxus sempervirens*, *Broussonetia papyrifera*, *Bursera serrata*, *Butea frondosa*, *Cactus* sp., *Caesalpinia bonducella*, *Canna indica*, *Callicarpa macrophylla*, *Calistemon rigidus*, *Calotropis procera*, *Carissa carandas*, *Cassia auriculata*, *C. fistula*, castor (*Ricinus communis*), *Cedrela toona*, *Celastrus paniculata*, *Celtis* sp., *C. australis*, *Ceratinia siliqua*, *chandni* (*Calonyction roxburghii*), *Citrus* spp., *Citharexylum subserratum*, *Clematis paniculatus*, *Clerodendron phlomoides*, *Cordia* sp., *C. myxa*, *C. obliqua*, *C. rothii*, *Crataeva religiosa*, *Croton tiglium*, *Cocculus laurifolius*, *Dalbergia lanceolaria*, *dharek* (*Melia azadirachta* and *M. composita*), *Diospyros embryopteris*, *D. montana*, duranta (*Duranta ellisi* & *D. plumieri*), *Ehretia serrata*, *Eriobotrya japonica* (Japan Medlar), *Erythrina crista galli*, *Eucalyptus* spp., *Eugenia jambolana*, *Feronia elephantum*, *Ficus* sp., *F. elastica*, *F. infectoria*, *F palmata*, *F. retusa*, *F. roxburghii*, fig. (*F. carica*), *Gmelina arborea*, *Grewia asiatica*, *guava* (*Psidium guyava*), *gular* (*Ficus glomerata*), *gul-i-fanus* (*Lager stroemia indica*), *Hiptage madablota*, *imli* (*Tamarindus indica*), *Inga dulcis*, *Ipomaea* sp., *Jasminum* sp., *Kigelia pinnata*, *Lonicera chinensis*, *Maclura aurantiaca*, *Magnolia grandiflora*, *Mallotus philippinensis*, *Mangifera indica*, *Melia indica*, *Mimusops elengi*, *M. Kauki*, *Mirabilis jalapa*, *Moringa pterygosperma*, mulberry (*Morus* sp., *M alba* and *M. laevigata*), *Murraya exotica*, *Musa sapientum*, *Myrtus communis*, *Nephelium litchi*, *Nerium* sp., *Nyctaginacea* sp., *Nyctanthes arbor-tristis*, oak (*Grevillea robusta*), *Ochna squarrosa*, *Olerodendron inerme*, *Opuntia* sp., *Oroxlum indicum*, *Phoenix* sp., *pipal* (*Ficus religiosa*), *Pistacia integerrima*, *Poinsettia* sp., *Pongamia glabra*, *Poplar* sp., *Populus alba*, *Porana paniculata*, *Pterospermum acerifolium*, *Punica granatum*, *Putranjiva roxburghii*, *Pyrus sinensis*, *Quisqualis indica*, *Rhamnus persicus*, *Rosa* sp., *Salix tetrasperma*, *sanatha* (*Dodonaea viscosa*), *Sapindus detergens*, *Sapium sebiferum*, *Saraca indica*, *shisham* (*Dalbergia sissoo*) (Plate LII, fig. 3), *Stephegyne parviflora*, *Sterculia* sp., *S. alata*, *Swietenia mahagoni*, *Tabernaemontana coronaria*, *Tecoma australis*, *T. stans*, *T. undulata*, *Terminalia arjuna*, *T. belerica*, *Thunbergia grndiflora*, *Ulmus* sp., *U. integrifolia*, *Vitex negundo*, *Vitis vinifera*, *Wrightia coccinea*, *zard kaner* (*Nerium oleander*), *Zizyphus* sp. and *Z. jujuba*.

Other workers have found it on the following plants: *Anacardium occidentale*, *Atylosia candollei*, *Bauhinia* sp., *Calotropis* sp., *Carissa* sp., *Chlorxylon swietenia*, *Cocos nucifera*, *Dalbergia* sp., *Hygrophylo spinosa*, *Limonia alata*, *Manihot glaziovii*, *Osbeckia* sp., *Panicum* sp., *Polyalthia* sp., *Scheleichera trijuga*, *Solanum* sp., *Solanum melongena*, *Tephrosia* sp. [Ramachandran and Ayyar, 1934].

Chief characters

Female scale.—Length 1·47-1·64 mm., breadth 1·23-1·64 mm., thick, more or less circular, slightly convex, yellow to yellowish brown. Exuviae organge-yellow to orange-brown, central or situated slightly to one side.

Female.—Length 1·04-1·15 mm., breadth 1·01-1·18 mm., ovate, yellowish brown in early adult life, becoming roundish and yellowish brown at maturity.

Pygidium with four pairs of lobes and is retracted into prosoma : I pair of lobes stoutest, distinctly separated, disto-lateral margins emarginate. II pair smaller, otherwise similar to the I pair. III pair smaller than II, their outer margins with an almost median emargination. IV pair poorly developed, squat.

Incisurae present and filled with serrated plates : I incisura with two slender plates, which are distally serrated deeply. II incisura with two plates which are serrated distally. III incisura with three plates, each with a deeply serrated apex. IV incisura with three plates, the median arm of each plate being large and produced posteriorly.

Sub-dorsal ducts one-barred, long, filiform, and confined to the sub-marginal region only where they are disposed of in groups ; six pairs of paraphyses also present.

Ventrum furnished with perivulvar pores which are arranged in five groups.

This species resembles San José scale in the shape of the scale and in general colour and shape of the body of the female. It can be separated from San José scale by the : (1) colour of the scale which is yellow, (2) three pairs of well-developed lobes and one pair of rudimentary lobes (these appear as a point), (3) well-developed and serrated plates the last group of which is club-shaped, and (4) presence of five groups of perivulver pores.

4. *CHRYSOMPHALUS FICUS* ASHMEAD : RED SCALE OF FLORIDA

Newstead, R. 1901 : Mon. Brit. Cocc. *London, I : 104*

Distribution

Lahore, Lyallpur, Multan, Sargodha and Sialkot. It has also been recorded from Anantpur, Bombay, Calcutta, Cochin, Coimbatore, Maddur, Mysore, Nilgiris, Penukonda, Poona and Malabar [Ramachandran and Ayyar, 1934].

Food plants

Cassia auriculata, *C. occidentalis*, *Citrus* sp., *Feronia elephantum*, *Ficus* sp., and *jaman* (*Eugenia jambolana*). It has also been recorded from the following plants : *Areca catechu*, bamboo, *Cocos nucifera*, *Garcinia indica*, *Mangifera indica*, palms, *Pandanus* sp. *Phoenix* sp., *Rhododendron* sp. and *R. arboreum* [Ramachandran and Ayyar, 1934].

Chief characters

Female scale.—Length 1·97-2 mm., breadth 1·88 mm., circular or moderately so, slightly convex, rather flat, dark reddish brown. Exuviae crimson or dark orange with brown depositions, central or very slightly to one side.

Female.—Length 1·1-1·31 mm., breadth 1·18 mm., ovate and yellowish in early adult life, becoming almost roundish at full maturity. Extremeties of the posterior thoracic margins provided with thoracic tubercles.

Pygidium, broader than long, with three pairs of rather equal lobes : I pair very stout, distinctly separated, their outer margins medially emarginate, and their outer anterior angle with a small seta. II pair similar to the I pair but smaller and with a little deeper emargination, their inner lateral mrgin usually entire, occasionally slightly notched, the small basal setae being

located medially on its base. III pair similar to II pair but smaller. Pygidial margin laterad to the III pair of lobes, strongly sclerotized with two equidistant emarginations.

Incisurae present, filled with variously fimbriated plates. I incisura with two plates which are serrated distally. II incisura with two plates which are deeply serrated distally. III incisura with one weaker and two stronger plates, all distally serrated. IV incisura with three stout plates, the anterior and the median arm of each plate being large but slender and produced posteriorly.

Sub-dorsal, one-barred ducts slender, narrow, arising from about the posterior margin of the abdomen, each connected with three dorsal rows of macropores, which are 1-2 in the marginal, 18 in the sub-marginal, and about 22 in the sub-median group. Median group composed of 3-4 stout ducts, which arise from macropores between I and II pair of lobes and extend up to about the middle of pygidium. 1-2 scattered ducts also met with.

Four dorsal scleroses are transversely placed just near the anterior pygidial margin.

Ventrum with five groups of perivulvar pores, median group usually scattered and never making up a definite group, sometime lacking. Microducts few, present along the margin only.

The scale of this species resembles that of San José scale in shape and colour, the females of the two being also identical. It differs from San José scale in the following characters: (1) Four pairs of lobes, three pairs being well developed, and the IV pair being represented by a rounded projection (2) Pygidial plates well developed, and (3) Five groups of perivulvar pores.

5. *Quadraspidiotus* (*Aspidiotus*) *perniciosus* (Comst.)

Comstock, J. H. 1881: Rep. U. S. Dept. Agric., 1880, *p. 304*

Distribution

Punjab.—Simla Hills: Dagshai, Darora, Dhagi, Dhar, Dhari, Kaithu, Kaliana, Kasauli, Khanog, Kiyar, Kotgarh, Kotkhai, Kufri, Loga, Loshta, Marela, Mashobra, Phagu, Rhoga, Sabathu, Subathu Cantt., Salogra, Shainhan, Simla, Solan, Summer Hill, Thanadar.

Simla Hill States: Balsan (Balsan State), Balu (Mandi State), Chaku (Koti State), Gutkar (Mandi State), Jhiri (Mandi State), Jogindar Nagar, Jubbal town (Jubbul State), Kiyar (Koti State), Kuptu (Koti State), Mandi proper, Nagwain (Mandi State), Rajpura (Chamba State), Sundar Nagar (Suket State), Tandu (Mandi State), Tatal (Madhan State).

Kulu Valley: Ani, Aramgarh, Arsu, Bahu, Bandrol, Bajaura, Banuri, Chowai, Deem, Dhaogi, Dhara, Dhobi, Haripur, Jibi, Jagat Sukh, Katrain, Kulu, Manali, Naggar, Nigali, Ohalpur, Palampur, Pati, Raison, Sharar, Trimli, Urthu.

Gurdaspur district: Dalhousie, Banikhet.

Murree Tehsil: Lower Rewat.

Kashmir Valley: Achhabal, Baramula, Harwan, Islamabad, Khanabal, Srinagar.

United Provinces.—Saharanpur, Chaubattia (Almorah district), Mussoori (Dehra Dun district).

N.-W. F. Province—Peshawar.

Hazara district : Abbotabad, Boi (Pattan side), Kakul, Malikpur, Oghi (Agror Valley).

Kurrum Valley : Agra, Alizia, Bilyamin, Gharbina, Kirman, Lukmankhel, Malana, Parachinar, Shalozan, Shingak, Shublan, Sultan, Ziran.

South Waziristan Agency.—Wana.

Food plants

Akik (*Canna indica*), alder (*kosh : Alnus nepalennis* and *A. nitida*), almond (*Prunus amygdalus*), wild almond (*Prunus* sp.), *alubukhara* (*Prunus divaricata*), apple (*Pyrus malus*), crab apple (*Pyrus* sp.), apricot (*Prunus armeniaca*), wild apricot (*Prunus* sp.), *arghanjo* (Parachinar wild plants : *Pyrus* sp. and *Prunus* sp.), *bhang* (*Cannabis sativa*), chestnut (*Castanea sativa*), cherry (*Cerasus vulgaris*), wild cherry (*Prunus* sp.), hawthorn (*Crataegus* sp.), lilac (*mahan : Ulmus* sp.), oak (*Quercus dilatata*), peach (*Prunus persica*), wild peach (*Prunus* sp.), pear (*Pyrus communis*), wild pear (*shegal*, *batangi*, etc. *P. pashia*), plum (*Prunus cummunis*), *cherai* (Parachinar local plum : *Prunus* sp.), Japan plum (*P. japonica*), wild plum (*Prunus* sp.), quince (*Cydonia vulgaris*), *siris* (*Albizzia lebbek*), walnut (*Juglans regia*), willow (*Salix* sp.); rose (*Rosa* sp.) and Persian rose (*Rosa* sp.).

The attacked plant becomes grayish in colour and appears scurfy and scabby. The infested fruit develops prominent scarlet circular areas at the point of infestation.

Chief characters

Female scale.—Length 1·31-1·64 mm., breadth 1·15-1·31 mm., almost circular, slightly convex, grayish. Exuviae yellowish brown with dark gray mid-dorsal cover, almost circular.

Female.—Length 0·91-1·48 mm., breadth 0·75-1·23 mm., ovate or almost circular, yellowish.

Pygidium acute, with three pairs of lobes [Rahman, 1940]. I Pair of lobes large, strongly sclerotized, deeply notched about midway on the outer margins. II pair of lobes smaller, strongly sclerotized, conspicuously notched on the outer margin. III pair of lobes rudimentary, represented by a triangular projection.

Incisurae furnished with plates. I incisura with a pair of small setaceous plate. II incisura with one setaceous and one narrow plate which is finally serrated dorso-laterally. III incisura with three narrow plates, serrated dorso-laterally. Three low, broad plates laterad of the III lobe.

Dermal sclerotic areas well defined along the margin and sub-median areas.

Sub-dorsal, one-barred, tubular ducts short, narrow, about 24 in number, connected with dorsal circular pores arranged in four definite groups, as well as scattered at random.

Ventrum without perivulvar pores, ventral ducts very few, narrow and short. Pygidial ventral inter-incisural scleroses (densariae) are well developed.

6. *Aspidiotus destructor* Sign.,: Bourbon aspidiotus

Ferris, G. F. 1938 : Atlas of scale insects of North America, *S. II* : *191*

Distribution

Amritsar, Jind, Lahore, Lyallpur, Multan, Muzaffargarh, Pataudi, Sufidan and Sangrur (Jind State) in the Punjab and Bannu and Dera Ismail Khan in the N.-W. F. Province. It has also been recorded from Anantpur, Bombay, Bengal, Ceylon, Coimbatore, Gujrat, Kumbalenguna, Laccadives, Malabar, Mundanthurai, Mysore, Nilgiris, Pusa, South Canara, Tinnevelly and Wynad [Ramachandran and Ayyar, 1934].

Food plants

Banana (*Musa sapientum*), *Bauhinia* sp., *Jasminum* sp., mango (*Mangifera indica*) and *Psidium guyava*. It has also been recorded on *Alocasia* sp., *Camellia thea*, *Calotropis* sp., *Carissa* sp., *Cassia* sp., *Citrus* sp., *Cocos nucifera*, *Eugenia* sp., *E. jambolana*, *Gelonium lanceolatum*, *Loranthus* sp., *Maesa indica*, *Musa paradisiaca*, *Piper nigrum*, *Phoenix* sp., *P. dactylifera*, *Psychotria* sp., *Ricinus communis*, rubber, *Solanum melongena*, *Tamarindus indica* [Ramachandran and Ayyar, 1934].

Chief characters

Female scale.—Length 0·74 mm., breadth 0·65 mm., very thin, circular, very slightly convex, whitish yellow. Exuviae pale yellow, central.

Female.—Length 0·59-0·65 mm., breadth 0·52 mm., ovate, yellowish with pygidium deep yellow.

Pygidium with three pairs of sub-equal lobes. I pair of lobes prominent, well separated, their margins distally emarginate. II pair of lobes emarginate on outer margins only. III pair of lobes similar to II pair but smaller.

Incisurae furnished with long prominent plates. I incisura with two stout plates. II incisura with two plates. III incisura with three plates, one of which is lacinate. There are six to seven plates beyond the III pair of lobes also.

One-barred dorsal ducts moderately long and narrow, and arranged in four groups.

Ventrum with four to five groups of perivulvar pores.

The adult female of this species resembles the adult female of San José scale in colouration and shape and in the number of lobes on the pygidium. It differs from it as follows : (1) Scale very thin and parchment-like, (2) Three pairs of well-developed but narrow lobes, (3) About 15 fimbriated plates along each pygidial half, and (4) Perivulvar pores present.

7. *Aonidia zizyphi* sp. n.

Puparium of female 1·1-1·2 mm. long, 0·9-1·1 mm. broad, whitish gray, almost circular, convex dorsally. Exuviae yellow to dark orange, slightly towards the margin.

The first skin 0·28-0·39 mm. long, 0·26-0·37 mm. broad, orange-yellow ; antennae five jointed, a little longer than the space between them, last segment a little longer than the other four taken together. I pair of lobes

of the pygidium widely separated, tridentate apically and prominently notched on their outer margins, II pair of lobes tooth-like, III pair of lobes inconspicuous.

The second skin 0·88-1·2 mm. long, 0·8-1·1 mm. broad, almost circular and covers the female completely ; I pair of lobes of the pygidium prominent, slightly dentate apically and prominently notched on their outer margins ; II pair of lobes triangular ; III pair of lobes small but easily made out ; pygidial margin beyond the II pair of lobes provided with eight glandular spines, fimbriated plates absent. Dorsal ducts very small, confined to the margins only.

Adult female almost circular, yellowish to reddish brown, enclosed in a puparium, 0·65 mm. long and 0·73 mm. broad, with no lateral projections. Prosoma with no lateral ducts, abdominal segments with gland spines and lateral gland ducts. Antennal segment situated just behind the frontal margin, is bidentate, and has a long bristle (Plate LI, fig. 4) ; spiracles as in other species, but the I pair with three parastigmatic pores, which are arranged in the form of a triangle.

Pygidium without perivulvar pores; I pair of lobes fairly well developed, basally convergent and apically divergent, disto-lateral margin emarginate, II pair of lobes small, triangular and without emargination. Pygidial margin laterad of II pair of lobes, distinctly irregular, fringed with eight setae as shown in the figure. Pectinae or plates are entirely wanting. Anal orifice small, quite near the median lobes. Dorsal pores marginal, sub-dorsal ducts very few, small, slender, and thread-like.

Distribution

Bannu, Ghoriwala, Nar Sabat Shah (Bannu), Nartahal Ram (Bannu) and Nurar Road.

Food plant

Zizyphus jujuba (Plate LIII, fig. 1).

Holotypes.—Female puparia from Bannu (Nartahal Ram) on *Zizyphus jujuba*, in the Entomological Laboratory, Punjab Agricultural College, Lyallpur.

This species resembles *Aonidia shastae* (Coleman) [Ferris, 1938] from which it is separated by the absence of fimbriated plates on the pygidial margin.

The scale of this species resembles San José scale in its form and colour, specially when II stage puparium is exposed. The female differs from that of San José scale in the : (1) absence of serrated plates, (2) dorsal ducts being very short and distributed along the margins only, and (3) presence of two pairs of lobes on the pygidium.

8. *Parlatoria oleae* (Colv.) : Olive parlatoria

Ferris, G. F. 1937 : Atlas of the scale insects of North America, *S. I* : *97*

Distribution

Punjab.—Ahmadgarb (Bahawalpur State), Aleo (Nabha State), Arazi (Kahuta Tehsil), Bahawalpur, Balao (Theog State), Bansragali (Murree), Barian (Murree), Bhagali (Banjar), Bhanuri, Bilaspur, Chabiana (Bahawalpur State)

Charhan (Murree), Chattar (Murree), Dera Nawab (Bahawalpur State), Dharampur (Simla), Dharamsala, Dhami, Dujana, Ghoragali (Murree), Gurdaspur, Jind, Jullundur, Junga (Keonthal State), Kalka, Katrain, Kherpur (Bahawalpur), Kiyar (Koti State), Kumarsain, Loharu, Luan (Kumarsain), Lyallpur, Madhan, Malerkotla, Mashobra (Simla), Masot (Murree), Mukerian, Mul Bhaji (Bhaji State), Nabha, Narkanda (Kumarsain State), Palampur, Parola (Theog State), Pataudi, Raison, Rawalpindi, Rewat (Murree), Sabathu (Simla), Saidpur, Sambli (Murree), Sanawar, Shali (Theog State), Simla, Sowl, Topa (Murree).

N.-W. F. Province.—Bannu, Boorki (Parachinar), Dadar (Hazara), Darsamand, Ghoriwala (Bannu), Hangu tehsil, Jandota (S. Waziristan), Kasar Fatehkhel, Lookmankhel, Lora village, Lundidak, Mirjamal, Mistakhel, Paharpur, Parachinar, Shablan (Parachinar), Shingok, Wana and Ziran (Parachinar). It has also been recorded from Central India, Madras and Pusa [Ramachandran and Ayyar, 1934].

Food plants

Crab apple (*Pyrus* sp.), apple (*Pyrus malus*), apricot (*Prunus armeniaca*), arghanju (Parachinar wild plant : *Prunus* sp.), *Caragana ambigua*, *dharek* (*Melia composita*), *gula-i-fanus* (*Lagerstroemia* sp.), *hari* (*Prunus* sp.), *Jasminum sambac*, *J. pubescens*, *kaint* (*Pyrus* sp), *kaner* (*Nerium odorum* and *N. oleander*), *kosh* (*Alnus nepalensis* and *A. nitida*), *loghuna* (Parachinar wild plant), loquat (*Eriobotrya japonica*), *Mangifera indica*, *Melia azadirachta*, *nim* (*Melia indica*), olive (*Olea europaea*), peach (*Prunus persica*) (Plate LIII, fig. 2), wild pear (*Pyrus pashia*), pear (*Pyrus communis*), persimmon (*Diospyros kaki*), plum (*Prunus communis*), *taklu* and *wang* (Parachinar local plants) and *Zizyphus jujuba*. It has also been recorded as *P. calianthina* B. & L. on *Michelia* sp. [Ramachandran and Ayyar, 1934].

Chief characters

Female scale.—Length 1·23-1·64 mm., breadth 1·06-1·31 mm. ovate or slightly round, convex, whitish gray to pale gray. Exuviae yellowish brown, apical.

Female.—Length 0·69-0·85 mm., breadth 0·57-0·65 mm., ovate, whitish yellow to yellowish brown, excepting pygidial centre which is pinkish-yellow.

Pygidium with four pairs of lobes : I pair of lobes well developed and distinctly separated, outer margins alone deeply notched. II and III pairs slightly smaller than the I pair, otherwise similar to it. IV pair very small, ill-defined, triangular.

Incisurae furnished with broad plates : I incisura with a pair of very short, narrow plates, the distal margins of which are poorly bifurcated. II incisura with two slightly stronger, narrower plates with at least three distal furcae. III incisura with three similar plates, but broader than the preceding ones. IV incisura with 4 plates, sub-equal, irregularly furcated on the distal margins. Three plates beyond IV incisura, slightly different in depth of dentation : four to five plates succeeding these are bluntly dentate and tuberculate.

Sub-dorsal, two-barred ducts numerous, broader and smaller. Margina ducts broader and smaller and opening in very heavily sclerotized semi-lunar

oral scleroses. The rest comparatively smaller, distributed along lateral margins of the abdominal segments only.

Ventrum with three groups of glandular tubercles on thorax : five groups of perivulvar pores disposed of as shown in the figure. Micro-ducts few, small, disposed of along the margins of the abdominal region.

This species resembles the San José scale in the colour of the scale which is surrounded by a reddish inflamed area. It differs from the San José scale as follows : (1) Four pairs of lobes (three well-developed, 4th ill-defined), (2) About 18 plates on each pygidial half, (3) Five groups of perivulvar pores, and (4) Sub-dorsal ducts two-barred and numerous.

9. *Parlatoria pseudopyri* Kuwana

Takahashi, R. 1938 : Proc. Roy. Ent. Soc. London, (B) vii 12 : *272*

Distribution

Punjab.—Amritsar, Bhawalpur, Bannu, Bahakkar, Dera Nawab (Bahawalpur State), Dujana, Gobindgarh, Jind, Kalka, Kherpur (Bahawalpur State), Lahore, Loharu, Lyallpur, Malerkotla, Muzaffargarh, Multan, Pataudi, Rawalpindi, Sangrur (Jind State) and Texila.

N.-W. F. Province.—Bannu, Darsamand, D. I. Khan (Musazai and Bilot) Serai Narang, Shabqaddar and Wana.

Food plants

Almond (*Prunus amygdalus*), apple (*Pyrus malus*), *bael* (*Aegle marmelos*), *Bauhinia* sp., *B. alba*, *B. purpurea*, *B. vahlii*, *B. variegata*, *Boswellia serrata*, *Buxus sempervirens*, *Buddleia mapagascamensis*, *Calotropis procera*, *chandni* (*Calonyction roxburghii*), *Cestrum nocturnum*, *Celastrus paniculata*, *Croton tiglium*, *Cryptostegia grandiflora*, *Cocculus laurifolius*, *dharek* (*Melia* sp. and *M. azadirachta*), *Ebenacea* sp., *Eugenia jambolana*, *Euonymus japonicus*, *Flacourtia sapida*, *gul-i-fanus* (*Lagerstroemia indica*), *Haematoxylon campachianum*, *Hamelia patens*, *Hibiscus mutabilis*, *H. rosa-sinensis*, *H. tiliaceus*, *Hypericum cernum*, *Jagan booti* (Bahawalpur local plant), *junga* (A Parachinar shrub), jasmine (*Jasminum arborescens*, *J. humile*, *J. pubescens* and *J. sambac*), *kaner* (red and white flowers:—*Nerium odorum* and *N. oleander*), *Lonicera chinensis*, *lasura* (*Cordia myxa*, *C. obliqua* and *C. rothii*), loquat (*Eriobotrya japonica*), mango (*Mangifera indica*), *Myrtus communis*, *Nandia domestica*, *Nephelium litchi*, *nim* (*Melia indica*), *Nyctanthes arbor-tristis*, *Ochna squarrosa*, *phalsa* (*Grewia asiatica*), *pipal* (*Ficus religiosa*), *Prunus divaricata*, *Prunus persica*, *Prunus communis*, *Pyrus sinensis*, *Rhamnus persicus*, *Rosa* spp. (Plate LIII, fig. 2) *Rubus fruticosus*, *Spirae corymbosa*, *Tabernaemontana coronaria*, *Urena lobota*, *Vitis* sp. *Woodfordia floribunda* and *Zizyphus* sp.

It is recorded for the first time from India. We believe it to be present in all places where rose is grown. At Lyallpur there was very heavy infestation on rose in 1937-38. An unidentified chalcid parasite and a coccinellid (*Thea bisoctonotata* Mul.) checked it very successfully at Lyallpur.

Chief characters

Female scale.—Length 1·64-1·8 mm., breadth 1·15-1·45 mm., oval, convex whitish gray to dark gray. Exuviae pale yellow and apical.

Female.—Length 0·82-1·00 mm., breadth 0·71-0·82 mm., pyriform, translucent, yellowish pale, pygidium being deeper yellow.

Pygidium with four pairs of lobes : I pair of lobes stoutest, well separated, deeply notched on both sides. II pair smaller and narrower than I, deeply notched only on the outer margin. III pair similar to II pair, but smaller. IV pair rudimentary, without notches.

Incisurae furnished with broad serrated plates : I incisura with two narrow spine-like plates which are distally serrated. II incisura similar to the I incisura. III incisura with one seta-like and two serrated plates. IV incisura with two strong and broad, distally truncate plates and one narrow, setaceous plate. About 16 broad and strong plates beyond, all of them more or less similar in form but differing in size and degree of dentation.

Sub-dorsal two-barred ducts small, scattered, quite numerous in the sub-marginal region of the pygidium. Marginal ducts broader, opening in heavily sclerotized semi-lunar scleroses : sub-marginal ducts narrower and smaller.

Ventrum with two groups of glandular tubercles on the thoracic region and one such group near the perivulvar pores. Four groups of perivulvar pores are present. Micro-ducts very few or obsolete.

This species closely resembles *P. olea* (Colv.). For characters by which it resembles San José scale as well as those by which it differs from it see under *P. olea* (Colv.).

10. *Lapazia peshawarensis* sp. n.

Puparium of female 0·82-1·18 mm. long, 0·36-0·51 mm. broad, elongate, whitish gray to yellowish gray, convex, excepting apical third which is flattened. Larval pellicles terminal, reddish brown, covering at least half of the scale.

The first skin 0·29-0·38 mm. long, 0·16-0·19 mm. broad, yellowish red ; antennae six-jointed, proximal joint longer and setaceous ; I pair of lobes of the pygidium squat, widely separated ; II pair of lobes vestigeal ; pygidial margin furnished with two prominent spurs.

The second skin 0·59-0·74 mm. long, 0·25-0·41 mm. broad. I pair of lobes of the pygidium wider than long, notched at the apex, widely separated, II pairs of lobes smaller, triangular. Margin of the pygidium with four spur-like prominences ; each spur with a setaceous plate below it and a fifth plate inner to the I lobe of the pygidium. Six to eight marginal two-barred ducts present.

Adult female 0·59-0·64 mm. long, 0·21-0·33 mm. broad, elongate, fusiform, translucent white or slightly yellowish, pygidium always deeper yellow. Prosoma provided with a few lateral ducts throughout ; abdominal segments clear ; gland spines absent, glandular ducts present along the lateral margins. Antennae situated midway between the front and the mouthparts with a blunt tooth above and two stout setae below (Plate LI, fig. 8). Mouthparts normal, spiracles without parastigmatic pores.

Pygidium with two lobes : I pair well defined, broader than long, their lateral margins straight, and apical margins rounded and slightly notched at end. II pair smaller, dentate. Margin of pygidium with four spur-like prominences, each bearing an oval pore ; plates reduced, simple and spine-like, each with a micro-duct at its base.

I incisura with two setaceous plates. II incisura with one plate, one plate at the base of each glandular spur and two on abdominal segments. Two-barred sub-dorsal ducts somewhat irregularly distributed on metathoracic and abdominal segments, except on pygidium, where they are arranged roughly in marginal, sub-marginal and sub-median groups. Marginal ducts comparatively broader, sub-marginal and sub-median ducts varying generally from two to three and always arranged in a definite pattern. Their exact distribution and arrangement is shown in the figure. Anal opening just near the anterior pygidial margin. Vaginal opening almost central. Ventrum with very fragile micro-ducts which are not easily discernable. Perivulvar pores absent.

Distribution

Bannu, Charsadda, Darsamand, D. I. Khan, Malana, Mardan, Parachinar, Paharpur, South Waziristan (Sarwaki, Tanai and Wana), Taru Jabba and Thall.

Food plants

Plum (*Prunus communis*) and peach (*Prunus persica*).

Holotype.—Female puparia from Taru Jabba (Peshawar) on peaches, in the Entomological Laboratory, Punjab Agricultural College, Lyallpur.

This species was placed in the genus *Pinnaspis* by Dr Takahashi, but the authors differ from him because this genus includes those species which have strongly zygotic median lobes, and five groups of perivulvar pores: *Lapazia peshawarensis* does not possess these characters. Ferris [1937] described only one species of this genus and *Lapazia peshawarensis* does not resemble it.

The leaves attacked by this species develop grayish patches, tender shoots begin to dry up from their tips downwards.

It produces red spots on fruits, closely resembling those caused by San José scale. It differs from San José scale in the following features : (1) Scale elongate, (2) Adult female fusiform, (3) Two pairs of pygidial lobes, (4) Spur-like pygidial prominences, (5) Plates reduced and spine-like and (6) Dorsal ducts two-barred.

Summary

The Imperial Council of Agricultural Research, New Delhi, sanctioned a scheme in April 1937 for three years to carry out a survey of the Punjab and the N.-W. F. Province, in order to find out the distribution and food plants of San José scale. This survey brought to light nine other Coccidae of economic importance which closely resemble San José scale either in their morphology or in symptoms of their attack, and as such are usually mistaken for it. These Coccids are as follows :—*Aonidiella aurantii* (Mask.), *Aonidiella citrina* (Coq.), *Aonidiella orientalis* (Newst.), *Chrysomphalus ficus* Ashm., *Aspidiotus destructor* Sign., *Aonidia zizyphi* n. sp., *Parlatoria oleae* (Colv.), *Parlatora pseudopyri* Kuw. and *Lapazia peshawarensis* n. sp. Their distribution, food plants and the chief distinguishing characters together with the characters by which they can be separated from San José scale are discussed. Two

species, namely *Aonidia zizyphi* n. sp. and *Lapazia peshawarensis* n. sp., are new to science and they are described here for the first time.

ACKNOWLEDGEMENTS

We are grateful to the Imperial Council of Agricultural Research for providing financial assistance to carry out a survey of San José scale in the Punjab and N.-W. F. Province ; to Dr T. V. Ramakrishna Ayyar, Government Entomologist, Madras (Rtd.) for reading through the manuscript and suggesting useful alterations ; to the authorities of the British Museum, London, for getting our identifications confirmed from Dr Takahashi and to Dr Takahashi for promptly attending to our material.

REFERENCES

Ayyar, T. V. R. (1929). *Bull. Agric. Res. Inst. Pusa*, **197**

Borkhsenius, N. (1935). *Plant Prot.* **6**, 127-33 (In Russian, translation kindly supplied by Sir Guy A. K. Marshall)

Comstock, J. H. (1881). *Rep. U. S. Dept. Agric. 1880*, pp. 270-349

Ferris, G. F. (1937). *Atlas of the scale insects of North America, Series I*

——————(1938). *Atlas of the scale insects of North America, Series II*

Newstead, R.(1901). *Mon. Brit. Cocc.* **1**

——————(1903). *Mon. Brit. Cocc.* **2**

Rahman, Khan A. (1940,1). *Indan Farm.* **1**, 387-90

—————— (1940,2). *Final Report on the Combined Entomological Scheme, Punjab and N.-W. F. Province*

Ramachandran, S. and Ayyar, T. V. R. (1934). *Misc. Bull. Imp. Coun. Agric. Res.* **4**

Takahashi, R. (1938). *Proc. R. Ent. Soc. London (B)* **7**, 271-2

ABSTRACT

Scope and Use of Experiment Station Record. EDITORIAL ARTICLE: *Experiment Station Record* **84,** No. 4, April 1941

EXPERIMENT Station Record published by the United States Department of Agriculture is, as the name suggests, a record of experiment station accomplishments. The station material occupies half the 138 pages in each issue. A substantial portion is occupied by the research contributions from the Federal Department of Agriculture. The remaining space is available for abstracts from non-station and non-Department sources. In order to conserve space, station annual reports are not abstracted, as they are essentially progress reports, but all findings are enumerated. At present the major research developments in agriculture and home economics are being placed on record for the United States and Canada and other parts of the British Empire to the extent that this research is widely applicable to conditions in the United States of America. Special attention is also being given to contributions from Central and South America.

Apart from the Station and Department publications and a considerable number of exchanges, the principal channel through which material becomes available for abstracting is the Department Library. The Library receives 3,871 periodicals, according to the list published in 1936 (*Miscellaneous Publication 245 of the Department of Agriculture.*) Another publication of value to users of the *Record* is Miscellaneous Publication 337, *Abbreviations Used in the Department of Agriculture for Titles of Publications* (1939). This gives addresses and a key for single words which is helpful especially in identifying recent publications. These two publications will obviate many inquiries to the Office of Experiment Stations.

Copies of original publications from which abstracts are made cannot be sent as spare copies are not available. Requests for copies of Departmental publications should be made to the Office of Information. The publications of the State experiment stations are distributed by the individual institutions. Books and periodicals must be purchased from the publishers, but reprints of articles are sometimes obtainable from their authors or their institutions.

Probably the most striking development in documentation aids in recent years has been the application of photography to the making of copies. Through the operation of Bibliofilm Service by the American Documentation Institute in cooperation with the Department Library, photographic reproductions may now be obtained for purposes of research for virtually any article abstracted in the *Record*. These reproductions are available in two forms, photo-prints, which can be read without magnification, and microfilm furnished at much lower cost but requiring a magnifier or projecting apparatus. Order blanks and details for this service can be obtained from the Bibliofilm Service, care of the Library, United States Department of Agriculture, Washington, D. C. It is believed that for certain types of articles, such as short papers appearing in voluminous or relatively inaccessible proceedings, this service has many advantages.

The classification of abstracts in the *Record* follows a plan of many years' standing. Cross references are not employed, and users are advised to read related sections, e.g. the soil conservationist should read not only the section on soil but also the sections of Agricultural Meteorology, Agricultural Botany, Field Crops, Forestry, Agricultural Engineering, Agricultural Economics and even Rural Sociology. Ultimately the subject indexes are available regardless of sectional lines, but these indexes should not be too narrowly used.

The best method of using the *Record* as a guide to the accomplishments of the past half century is by means of the combined subject indexes. There are six of them and additions are made every five years. The second of the group covering vols. 13—25 is no longer available, but the others can be obtained free of charge by libraries and for institutional use. The Office of Experiment Stations is always glad to help in completing files for both the general indexes and the individual volumes. (Abstract)

REVIEWS

Handbook of economic entomology for South India. By T. V. Ramakrishna Ayyar (Superintendent, Government Press, Madras, 1940), pp. 528, Rs. 4-12-0

THIS is a timely book which will be of the greatest use to Indian entomologists. The first book on the insects of Madras, *Some South Indian Insects*, was published in 1914 by T. B. Fletcher, the Government Entomologist, Madras, during 1912-14, and later on the Imperial Entomologist, Pusa. Since then there has been a growing demand specially from students of agriculture and educated farmers for a handy, up-to-date volume on South Indian insects especially those of economic importance. Mr. Ayyar's work represents an attempt to meet such a demand. It will be specially useful to students of agricultural colleges because the plan of the book and the matter included in it form an elaboration of the college lectures on entomology which were given by the author to the students of the Madras Agricultural College for over 20 years. The book is divided into two parts ; (*i*) the general part of six chapters briefly giving some fundamental ideas of insects and their various activities, and (*ii*) a special part including general discussions on insect pests, some of the control measures against them, and a brief annotated summary of the important insects of economic importance so far recorded from South India on different crops. There are useful appendices on classification and control given at the end of the book. Credit is due to the Superintendent, Government Press, Madras, for the neat printing and the fine get-up of this useful volume. Mr. Ayyar deserves the congratulations of all agricultural workers for this very useful handbook. (S. C. R.)

The Grasslands of the Argentine and Patagonia. By William Davies (*Bulletin No.* **30**, *Herbage Publication Series, Imperial Bureau of Pastures and Forage Crops, Aberystwyth, G. B.*, 1940), pp. 46, 2*s*. 9*d*.

IN this *Bulletin* is published the report by Mr William Davies, Senior Grassland Investigator, Welsh Plant Breeding Station, Aberystwyth, of his tour of South American Grasslands. The object of Mr Davies' tour has been to study the present condition, and the potential and immediate possibilities of improvement of the grasslands of the Argentine Republic. For this purpose he travelled across the Republic in a south to north direction covering a vast distance in a short time. In all, 23 grass farms (stations) were visited ; and the visit was sufficient to give him an idea of the existing conditions. Even though it was not possible for him to survey the country in greater detail, the tour has furnished much information of importance.

The report of Mr Davies gives a short description of the climatic and geographical conditions of the Republic, which, because of its situation in a north to south direction, includes a variety of climates. The southern one-third of the Republic, which covers a greater portion of Patagonia, and which is

situated in the cold temperate region and is arid for a greater part of the year, is mostly under sheep ranching. The Argentine proper, in which is situated the La Plata Basin, has a mediterranean climate, and as such is of considerable agricultural and pastoral importance. Both cattle and sheep are maintained, but cattle are more important than sheep. In the northern portion, having a sub-tropical climate, chiefly cattle are reared.

Argentine Republic is the leading lucerne-growing country of the world and had over 13,000,000 acres under it in 1933-34. The peak production was during 1920-21, when there were over 20,000,000 acres under lucerne. According to Mr Davies, even this does not appear to be the limit to which its cultivation may be extended. It is pointed out that the Province of Buenos Aires and adjacent ones possess potentially the richest grazing land in the world, and it is significantly remarked, 'Were this land to be properly developed, it has the potentiality of vast output as a reservoir of human and animal food'. But Mr Davies states that if such a development takes place, it wolud set up a serious competition with the agriculture and livestock industry of Great Britain, the British Dominions and Colonies, particularly Australia and New Zealand. At present the livestock industry in Argentine is restricted to cattle feeding, but the dairy side, which is still undeveloped, has not materially competed in the past with Australia and New Zealand. It is pointed out that the Province of Buenos Aires if properly planned could be organized into an intensive dairying and fat lamb producing area. With the soil and climate possessed by Argentine, the potentialities for organizing dairying industry are so great that it would require very little, if any, outlay beyond the mere application of the technique of grassland improvement practised in Great Britain and New Zealand.

The remaining part of the report is devoted to a general consideration of the eight zones into which the grasslands of the Argentine Republic have been divided. The possibilities of improvement and methods to be adopted with respect to each zone are given. In the latter part of the report is published detailed notes on the 23 stations visited by Mr. Davies.

A large number of photographs, a map, a glossary of common plant names and figures relating to stock and crops have considerably enhanced the value of the report. (L. S. S. K.)

PLANT QUARANTINE NOTIFICATIONS

FOREIGN

THE following plant quarantine regulations and import restrictions have been received in the Imperial Council of Agricultural Research. Those interested are advised to apply to the Secretary, Imperial Council of Agricultural Research, New Delhi, for loan.

1. *Summaries of plant quarantine import restrictions*
   (*i*) Plant Quarantine Import Restrictions of the Kingdom of Iraq (Mesopotamia)
   (*ii*) Plant Quarantine and Import Restrictions of the Republic of Uraguay.
2. (*i*) Service and Regulatory Announcements—April-June 1940.
   (*ii*) Service and Regulatory Announcements—July-September 1940.
   (*iii*) Index to Service and Regulatory Announcements —1939.
3. *Other announcements*
   (*i*) Government of Burma, Department of Agriculture and Forests Notification No. 377, dated the 16th December 1940.
   (*ii*) Government of Burma, Department of Agriculture and Forests Notification No. 13 (corrigendum), dated the 15th January 1941.
   (*iii*) Government of Burma, Department of Agriculture and Forests Notification No. 56, dated the 28th February 1941.
   (*iv*) Government of Burma, Department of Agriculture and Forests Notification No. 89, dated the 24th April 1941.
   (*v*) North Borneo—
      (*i*) Agricultural Pests (Prohibited Plant) Rules, 1940.
      (*ii*) Notification No. 105—Schedule of charges in respect of inspections and fumigations.
      (*iii*) Notification No. 106—Giant Snail declared agricultural pest.

INDIA

Notification No. F./43-32(6)/40-A. issued by the Government of India in the Department of Education, Health and Lands

IN this Department Notification No. F.-43-32/40-A., dated the 16th January 1941, for the word ' fruits ' the words ' plant products ' shall be substituted.

GIPD—3 S—189 IC of AR—25-10-41—750.

List of Agents in India and Burma from whom Government of India Publications are available.

ABBOTTABAD—English Book Store.

AGRA—
English Book Depot, Taj Road.
Indian Army Book Depot, Dayalbagh.

AHMEDABAD—H. L. College of Commerce Co-operative Store, Ltd.

AJMER—Banthiya & Co., Ltd., Station Road.

AKOLA—Bakshi, Mr. M. G.

ALLAHABAD—
Central Book Depot, 44, Johnstonganj.
Kitabistan, 17-A, City Road.
Ram Narain Lal, 1, Bank Road.
Superintendent, Printing and Stationery, U. P.
Wheeler & Co., Messrs. A. H.

BOMBAY—
Co-operators' Book Depot, 9, Bakehouse Lane, Fort.
International Book House, Ash Lane, Esplanade Road.
Kothari Book Depot.
Lakhani Book Depot, Bombay, 4.
New Book Co., Kitab Mahal, 188-90, Hornby Road.
Popular Book Depot, Grant Road.
Superintendent, Govt. Printing & Stationery, Queen's Road.
Taraporevala Sons & Co., Messrs. D. B.
Thacker & Co., Ltd.
Tripathi & Co., Messrs. N. M., Princess Street, Kalbadevi Road.
Wheeler & Co., Messrs. A. H.

CALCUTTA—
Book Company.
Chatterjee & Co., 3, Bacharam Chatterjee Lane.
Chukervertty, Chatterjee & Co., Ltd., 13, College Square.
Das Gupta & Co., 54/3, College Street.
Hindu Library, 137-F, Balaram De Street.
Lahiri & Co., Ltd., Messrs. S. K.
Macmillan & Co., Ltd., 294, Bow Bazar Street.
Newman & Co., Ltd., Messrs. W.
Roy Chowdhury & Co., Messrs. N. M., 72, Harrison Road.
Sarcar & Sons, Messrs. M. C., 15, College Square.
Sarkar & Sons, Ltd., Messrs. S. C., 1/1/1-C, College Square.
Standard Law Book Society, 79/1, Harrison Road.
Thacker, Spink & Co. (1933), Ltd.
Wheeler & Co., Messrs. A. H.

CAWNPORE—
Advani & Co., P. O. Box No. 100.
Indian Army Depot. Juhi.

CUTTACK—Press Officer, Orissa Secretariat.

DEHRA DUN—
Jugal Kishore & Co.
Ideal Book Depot, Rajpur Road.

DELHI—
Imperial Book Depot and Press, Near Jama Masjid (Macchliwalan).
Incometax Law Publishing House, Chandni Chowk.*
Indian Army Book Depot, Daryaganj.
Jaina & Bros., Messrs. J. M., Morigate.
Oxford Book and Stationery Co.
Sharada Mandir, Ltd., Nai Sarak.
Young Man & Co. (Regd.), Egerton Road.

DEVGAD BARIA.—Joshi, Mr. V. G., News Agent (*via* Piplod).

DUM DUM CANTT.—Bengal Flying Club.†

FEROZEPUR—English Book Depot.

GWALIOR—Jain & Bros., Messrs. M. B., Sarafa Road.

HYDERABAD (DECCAN)—Hyderabad Book Depot, Chaderghat.

JAIPUR—Garg Book Co., Tripolia Bazar.

KARACHI—
Aero Stores.
English Bookstall.
Standard Bookstall.

KARACHI (SADAR)—Manager, Sind Government Book Depot and Record Office.

LAHORE—
Buckingham & Co., Book-sellers & Stationers, Ramgate.
Kansil & Co., Messrs. N. C., 9, Commercial Buildings, The Mall.
Malhotra & Co., Messrs. U.P., Post Box No. 94.
Minerva Book Shop, Anarkali Street.
Punjab Religious Book Society.
Rama Krishna & Sons, Anarkali.
Superintendent Govt. Printing, Punjab.
University Book Agency, Kacheri Road.

LUCKNOW—Upper India Publishing House, Ltd. Literature Palace, Aminuddaula Park.

LYALLPORE—Lyall Book Depot.

MADRAS—
Higginbothams.
Superintendent, Govt. Press, Mount Road.
Varadachary & Co., Messrs. P.

MHOW—British Book Depot.

MOGA—Army Musketry Stores.

NAGPUR—
Khot & Sons, Messrs. G. G., Sita Buldi, 3rd Modi Lane.
Superintendent, Govt. Printing, Central Provinces.

NEGAPATAM—Venkataraman, Mr. B.

NEW DELHI—
Bawa Harkishan Das Bedi, Ferozeshah Road.
Bhawnani & Sons.
Delhi and U. P. Flying Club, Ltd.†
Jaina & Bros. Messrs. J. M., Connaught Place.
Ramesh Book Depot & Stationery Mart, Connought Place.
Saraswati Book Depot, 15, Lady Hardinge Road

PATNA—Superintendent, Government Printing, Bihar, P. O. Gulzarbagh.

PATNA CITY—
Lakshmi Trading Co., Padri-Ki-Haveli.
Raghunath Prasad & Sons.
Sinha & Bros. Messrs. R. P. Guzri Bazar.

PESHAWAR—
British Stationery Mart.
London Book Co. (India), Arbab Road.
Manager, Govt. Printing & Stationery, N.-W., F. P.

PESHAWAR CANTT.—Faqir Chand Marwah.

POONA—
Deccan Bookstall, Fergusson College Road.
Dastane Bros., Home Service, 456, Rawiwar Peth.
International Book Service.
Ram Krishna Bros., Opposite Bishram Bagh.

QUETTA.—Standard Bookstall.

RAJKOT—Mohanlal Dossabhai Shah.

RANGOON—
Burma Book Club Ltd.
Curator, Govt. Book Depot, Burma.

RAWALPINDI—Ray & Sons, Messrs. J., 43, K. & L. Edwardes Road.

SHILLONG—Superintendent, Assam Secretariat Press.

SIALKOT CANTT.—Modern Book Depot, Bazar Road.

SIALKOT CITY—
Clifton & Co., Book-sellers and Musketry Store Suppliers.

TRICHINOPOLY FORT—Krishnaswami & Co., Messrs. S., Teppakulam.

TRIVANDRUM—
Booklovers' Resort, Taikad.
P. R. Bros, Main Road.

VELLORE—Venkatasubban Mr. A., Law Bookseller.

* Agents for Income-tax, Law and allied Publication only.

† Agents for Publications on Aviation only.

CONTENTS

VOL. XI, PART V

(October 1941)

The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal.

		PAGE
Original articles—		
THE GENUS *FUSARIUM*. VI. A RECENT ATTEMPT AT MASS REVISION	*G. Watts Padwick* . . .	663
STUDIES IN INDIAN CEREAL SMUTS, II. VARIETAL RESISTANCE OF INDIAN AND OTHER WHEATS TO LOOSE SMUT.	*B. B. Mundkur and B. P. Pal*	675
STUDIES IN INDIAN CEREAL SMUTS, III. VARIETAL RESISTANCE OF INDIAN AND OTHER WHEATS TO FLAG SMUT	*B. P. PAL and B. B. Mundkur*	687
STUDIES IN INDIAN CEREAL SMUTS, IV. VARIETAL RESISTANCE OF INDIAN AND OTHER OATS TO SMUTS	*R. D. Bose and B. B. Mundkur*	695
VARIATION IN THE MEASURABLE CHARACTERS OF COTTON FIBRES, II. VARIATION AMONG SEEDS WITHIN A LOCK	*R. L. N. Iyengar* . . .	703
STUDIES ON PROPAGATION OF THE MANGO .	*K. C. Naik*	736
THE COLD STORAGE OF PEARS IN THE PUNJAB .	*Lal Singh and Abdul Hamid* .	769
CITRUS MANURING, I. FERTILIZER EXPERIMENT WITH SWEET ORANGE (MALTA) GROWING ON ROUGH LEMON.	*Lal Singh, Bal Singh and A. A. Khan*	778
A KEY FOR THE IDENTIFICATION OF LARVAE OF THE KNOWN LEPIDOPTEROUS BORERS OF SUGARCANE IN INDIA BASED ON MORPHOLOGICAL CHARACTERS.	*P. V. Isaac and K. V. Rao* .	795
A KEY FOR THE IDENTIFICATION OF PUPAE OF THE KNOWN LEPIDOPTEROUS BORERS OF SUGARCANE IN INDIA BASED ON MORPHOLOGICAL CHARACTERS	*P. V. Isaac and T. V. Venkatraman*	807
SCALE INSECTS OF THE PUNJAB AND NORTH-WEST FRONTIER PROVINCE USUALLY MISTAKEN FOR SAN JOSÉ SCALE WITH DESCRIPTION OF TWO NEW SPECIES	*Khan A. Rahman and Atiqur Rahman*	816